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FY99 Lessons Learned from Central Energy Plant Modernization Site Visits

by William T. Brown, Michael K. Brewer, Charles P. Marsh, Vicki L. VanBlaricum, Gary E. Phetteplace, Martin J. Savoie, Vincent F. Hock, Phil J. Conner, and Henry C. Gignilliat

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Foreword

This study was conducted for the Office of Assistant Chief of Staff for Installation Management (OACSIM) under Work Unit GZ9, "Central Heating Utility Plant Modernization Program." The technical monitor was Henry Gignilliat, DAIM-FDF-FE.

The work was performed by the Energy Branch (CF-E) and the Materials and Structures Branch (CF-M) of the Facilities Division (CF), U.S. Army Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was William T. Brown III. Larry Windingland is Chief, CEERD-CF-E; Dr. Ilker R. Adiguzel is Chief, CF-M; and Dr. L. Michael Golish is Chief, CEERD-CF. The associated Technical Director was Gary W. Schanche, CEERD-CV-T. The CERL technical editor was William J. Wolfe, Information Technology Laboratory. The Acting Director of CERL is William D. Goran.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Director of ERDC is Dr. James R. Houston and the Commander is COL James S. Weller.

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1 Introduction

Background

The purpose of the Central Heating Plant (CHP) Modernization Program is to implement major repair or replacement projects for inefficient and failing heating plant systems so that the modernized plants and distribution systems will provide the installations with safe, reliable, energy-efficient, and environmentally friendly service.

Projects are funded and executed under the CHP Modernization Program according to the following general procedure:

1. The installation performs an analysis of upgrade alternatives and decides on the best one.
2. The installation prepares a DD1391 (*FY__, Military Construction Project Data [LRA]* [December 1976]) describing the proposed repair project and submits it to their MACOM.
3. The MACOM reviews the proposal, and if it is acceptable, approves and submits it to the Office of the Assistant Chief of Staff for Installation Management, OACSIM.
4. A survey team consisting of members of OACSIM, the Corps of Engineers Installation Support Center (CEISC), the Army Audit Agency (AAA), the U.S. Army Construction Engineering Research Laboratory (CERL) and/or the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), the installation MACOM representative, and the local District visits the installation and validates the requirement and proposed project.
5. OACSIM approves the proposal and prioritizes it for funding.
6. The project is designed. This step is usually funded by the installation and/or the MACOM. Installations are encouraged to use their local USACE district for design support.
7. During the fiscal year of the execution of the project, funding is released from the Army budget office to the MACOM. The MACOM transmits the funding to the installation.
8. The project is constructed and commissioned.

9. All projects are required to have an economic analysis to establish the most cost-effective repair alternative. Some installations have had their economic analyses and estimated project costs validated by the Army audit Agency (AAA).

The work that is done by the installation Directorate of Public Works (DPW) during the first two steps is critical in determining whether the project will receive funding, and whether it will be deemed a success when it is completed. To obtain funding, the DPW must select the best modernization alternative and put together a proposal that will best meet the selection criteria of the MACOM and the OACSIM. Alternatives need to be examined over the life cycle. Some of the examples are:

- maintain the status quo (for comparison to alternatives)
- refurbish or install new high efficiency equipment
- use low temperature hot water distribution
- use high temperature hot water distribution
- upgrade steam distribution system
- shut down boilers during the summer
- use cogeneration
- use decentralized local boilers supplied with natural gas
- use above ground, shallow trench, or direct buried systems.

Other options that would be considered include:

- Energy Savings Performance Contracts (ESPCs)
- Utility partnership energy service contracts.

To be deemed a viable modernization candidate, the project must have a documented requirement for repair or upgrade based on mission need and the failed or failing condition of equipment. A thorough economic analysis must be done by examining feasible options to determine the best repair alternative that results in the least life cycle cost. To qualify as an energy project, the Savings-to-Investment Ratio (SIR) must be greater than 1.0 over the life cycle of the project. The calculation of payback and benefits must be able to stand up under the scrutiny of the AAA. Findings from the AAA in fiscal years 1998 (FY98) and FY99 showed that savings are less than predicted, but that the heating plants are in poor to failing condition, and that projects are necessary. In general, results showed minimal short-term savings, but significant savings and cost avoidance accruing over the long-term, 25-year economic life of the project.

CERL previously published a technical report with general procedures and resources to help the DPW analyze modernization alternatives and prepare docu-

mentation on the DD1391 (Van Blaricum et al. 1999). This report provides observations and findings based on FY99 site visits.

Objectives

The objectives of this study were to:

1. Document tools and methods that provide useful results for successful CHP modernization projects, and
2. Provide lessons learned on the CHP Modernization Program survey team's FY99 site visits.

Approach

Data collected during several of the FY99 CHP survey team's site visits were compiled and analyzed. The site surveys are discussed in Chapters 2 through 5. Several CERL-developed analytic tools were used at the sites to help select and/or validate energy supply options. These tools include:

- *HEATMAP*. HEATMAP allows the engineer to run flow, pressure, and heat loss simulations for a steam, hot water, or chilled distribution system (Washington State Energy Office 1992). Simulations can be run for the existing system and for proposed modernization alternatives. HEATMAP also includes economic analysis capabilities. The only input needed for a HEATMAP simulation is an accurate map of the distribution system, along with basic data on the buildings served (area and building usage).
- *Energy Screening Tool*. This Microsoft Excel® spreadsheet generates site-specific curves relating the cost of energy delivered to a building to the peak building energy density. Curves are generated for a variety of energy supply options based upon data reported in the *Directorates of Public Works, Annual Summary of Operations*, commonly known as the "Redbook" (DA and/or data provided by the installation. This allows engineers to identify the most economical energy supply option for various areas of the installation based on typical demand in that area.
- *Corrosion Prediction Models*. These models can predict external (soil-side) corrosion and internal (waterside) corrosion based on soil and water chemistry. The models can predict an approximate year of failure for a given pipe system.

Some general procedures, resources, and hints were assembled to help installations develop and analyze CHP modernization alternatives.

Mode of Technology Transfer

The findings of this research effort will assist in the project development and selection for the CHP Modernization Program. The information presented here will help streamline the process for future year projects. It is recommended that the results be used to update Army guidance documents, including Army Regulation (AR) 420-49, *Utility Services* and Technical Manual (TM) 5-650, *Repairs and Utilities: Central Boiler Plants*.

Units of Weight and Measure

U.S. standard units of measure are used throughout this report. A table of conversion factors for Standard International (SI) units is provided below.

SI conversion factors		
1 in.	=	2.54 cm
1 ft	=	0.305 m
1 yd	=	0.9144 m
1 sq in.	=	6.452 cm^2
1 sq ft	=	0.093 m^2
1 sq yd	=	0.836 m^2
1 cu in.	=	16.39 cm^3
1 cu ft	=	0.028 m^3
1 cu yd	=	0.764 m^3
1 gal	=	3.78 L
1 lb	=	0.453 kg
1 kip	=	453 kg
1 psi	=	6.89 kPa
°F	=	(°C x 1.8) + 32

2 Redstone Arsenal Analysis

Site Visit at Redstone Arsenal, AL

The FY00/01 Utility Modernization Program Support Team met with the Redstone Arsenal Directorate of Public Works on 9-10 February 1999. Most of the modernization project at Redstone Arsenal involves refurbishing the centralized steam system. The replacement design establishes 18 central plants to supply building clusters with distribution lines to buildings run underground. The design includes asbestos removal and an environmental assessment (both required). The system includes a total of 60 miles of steam distribution, with 20 miles of distribution underground. Figure 1 shows a portion of the steam distribution system. The DD1391 indicates deficiencies in the steam distribution segment related to delivery point "a." The City of Huntsville Refuse-Fired Incinerator supplies the steam up to delivery point "a." The area served is the west-central portion of the installation originally served by the building 3624 gas/oil fired steam plant. The condensate return system is excessively costly to maintain, and preventive maintenance cannot be afforded to keep live steam from entering the condensate return system. The condition of the system is best represented by the penalty fees paid monthly. The average condensate penalty is approximately $25,000 per month, or about $300,000 per year. Delivery point "b," which serves the 5000 building area, was not addressed in the DD1391.

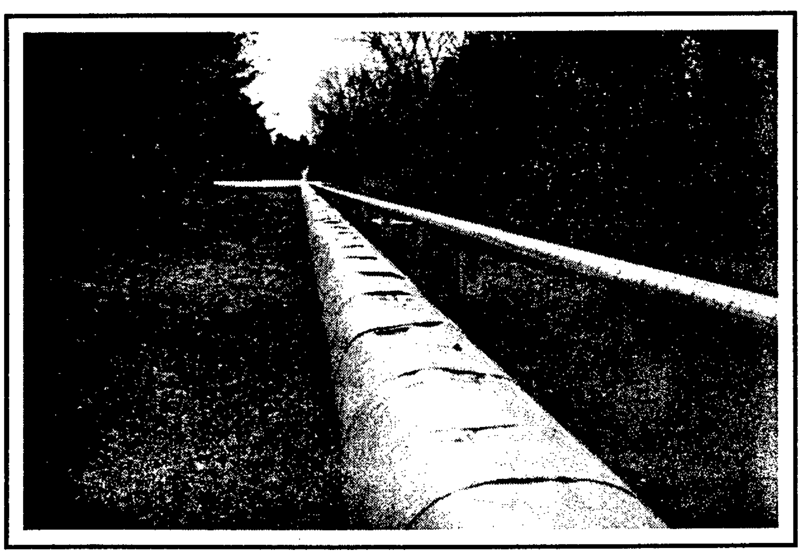

Figure 1. Steam distribution system lines.

Redstone Arsenal buys and pays for the steam, and the City of Huntsville accepts Redstone Arsenal's solid waste. The steam is used year-round. (It is also purchased in the summer for cooling.) Redstone Arsenal also considered using high temperature hot water distribution as an alternative for steam distribution.

Redstone Arsenal Public Works staff helped provide the team with a tour of the steam distribution lines and central plants affected by the modernization program. The team passed by the school area (3300), which is supplied by steam distribution lines from point "a." The old boiler plant (Building 3624) was viewed from the outside since it contains asbestos (Figure 2). A sample of condensate steam was gathered from Building 3628 to use for analysis. Table 1 lists the results of the analysis. The team then traveled to the metering station for point "a" (Figure 3) and noticed the city's distribution line that goes to point "a." The team also went to Building 5311, which feeds only the Sparkman Center (HQ AMCOM) area, and is designated point "c." Afterwards, the team went to Building 4725 (Figure 4), where there is a condensate collection point, called point "b." Point "b" was observed to have hydraulic problems between steam and condensate lines as the condensate now flows opposite to the intended direction. To reroute steam lines, military construction (MILCON) funds would be needed to handle the demolition. The team then viewed steam lines at another part of point "b" that exhibited steam leaks. Part of point "b" services the National Aeronautics and Space Administration (NASA) area. Figures 5 through 15 show additional pictures taken during the site visit.

Observations from Redstone Arsenal Site Visit

The penalty/reward for condensate return below/above 70 percent should be included in the economics. The overall layout of the existing lines certainly seemed to be extremely sub-optimal. An option should be studied using new aboveground lines that go directly to where the steam is needed. The DD1391 indicated that the ongoing "repairs" to the condensate lines: (1) do not seem to be effective, and (2) cost more than their yearly penalty, which was said to be about $300,000 (and likely to increase). The aboveground lines themselves overall seemed to be in above average to good shape, without taking into account the internal condition. If needed, the base from the metal supports could be reused. Some minor repairs and some re-insulation would be needed. The thermal expansion supports would also need to be checked because the bearing area was down to roughly 50 percent. Using a lower temperature would provide more bearing area while in operation. Redstone should analyze the feasibility of using HTHW or LTHW distribution to eliminate condensate losses.

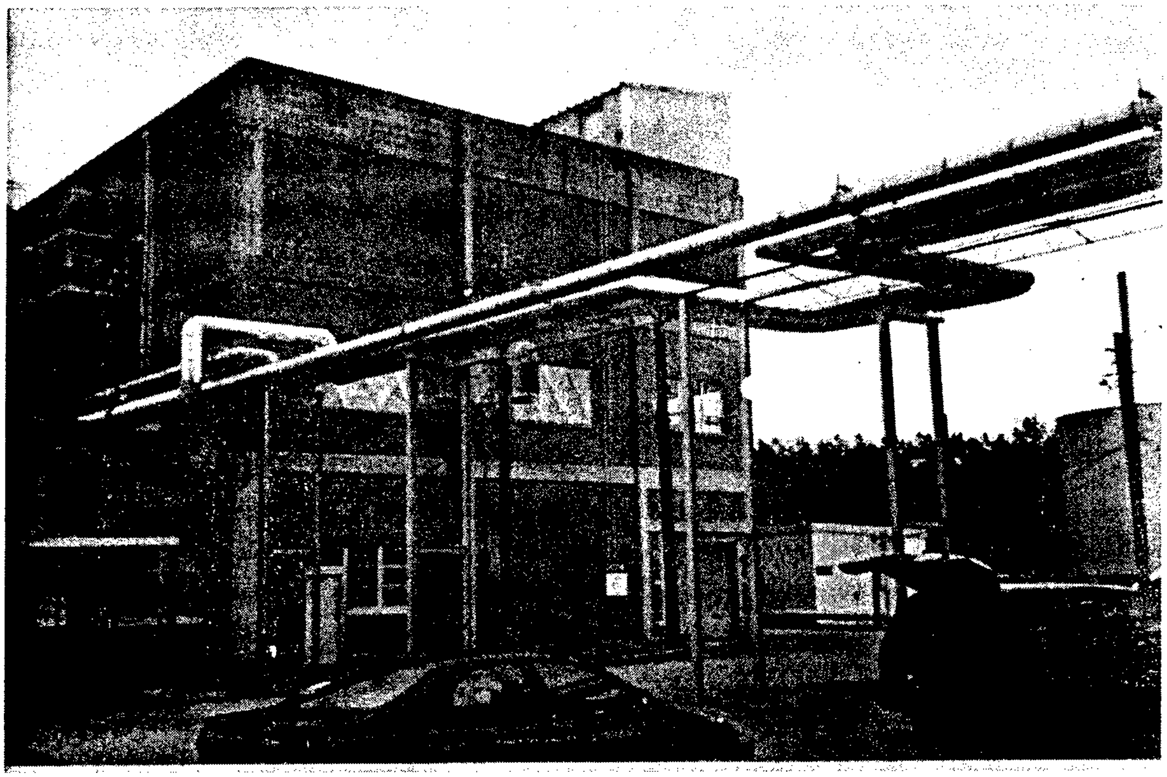

Figure 2. Old boiler plant (Building 3624).

Table 1. Redstone Arsenal water chemistry data.

Parameter	Condensate Sample from Building 3628
pH	9.76
Temperature (°F)	72.68
Ammonia (mg/L)	17.40
Calcium (mg/L)	1.81
Copper (mg/L)	0.03
Iron (mg/L)	0.46
Magnesium (mg/L)	0.14
Cyclohexylamine (mg/L)	0.7
Diethylaminoethanol (mg/L)	3.8
Morpholine (mg/L)	0.3
Total Hardness (mg/L)	5.10
Methyl Orange Alkalinity (mg/L)	72.00
Conductivity (μmhos/cm)	116.00

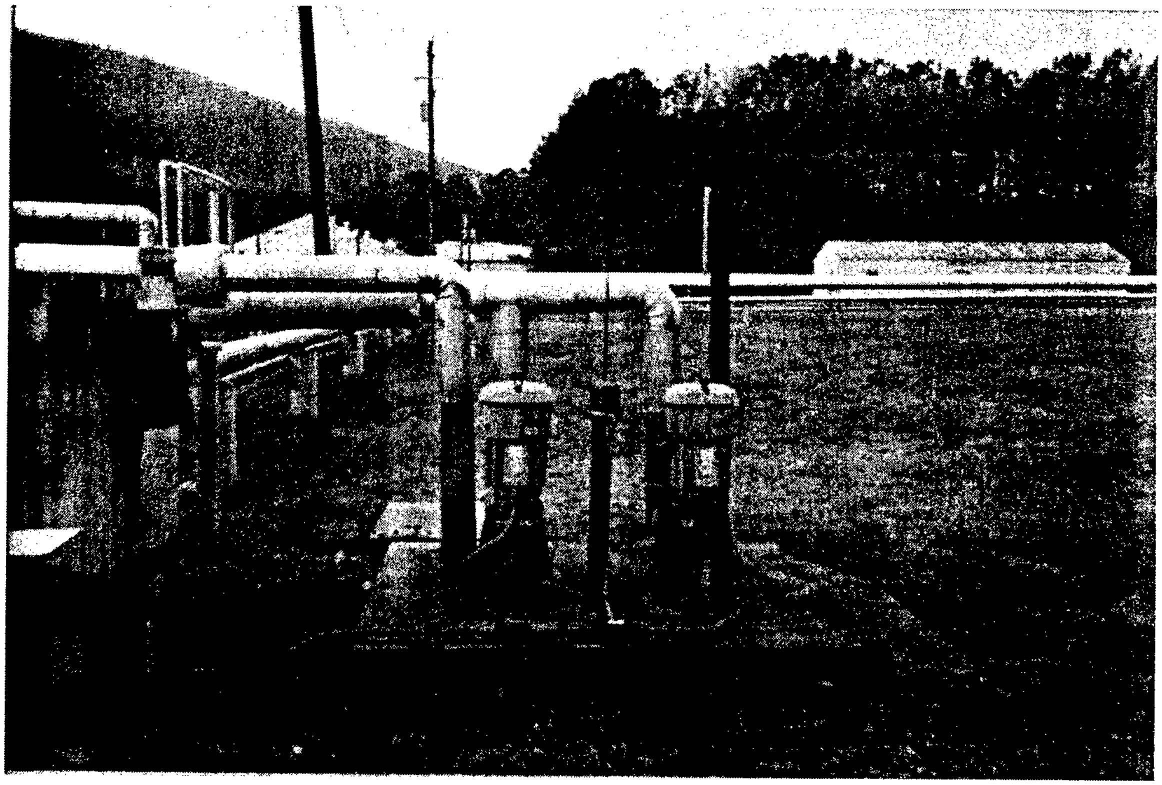

Figure 3. Metering station for point "a."

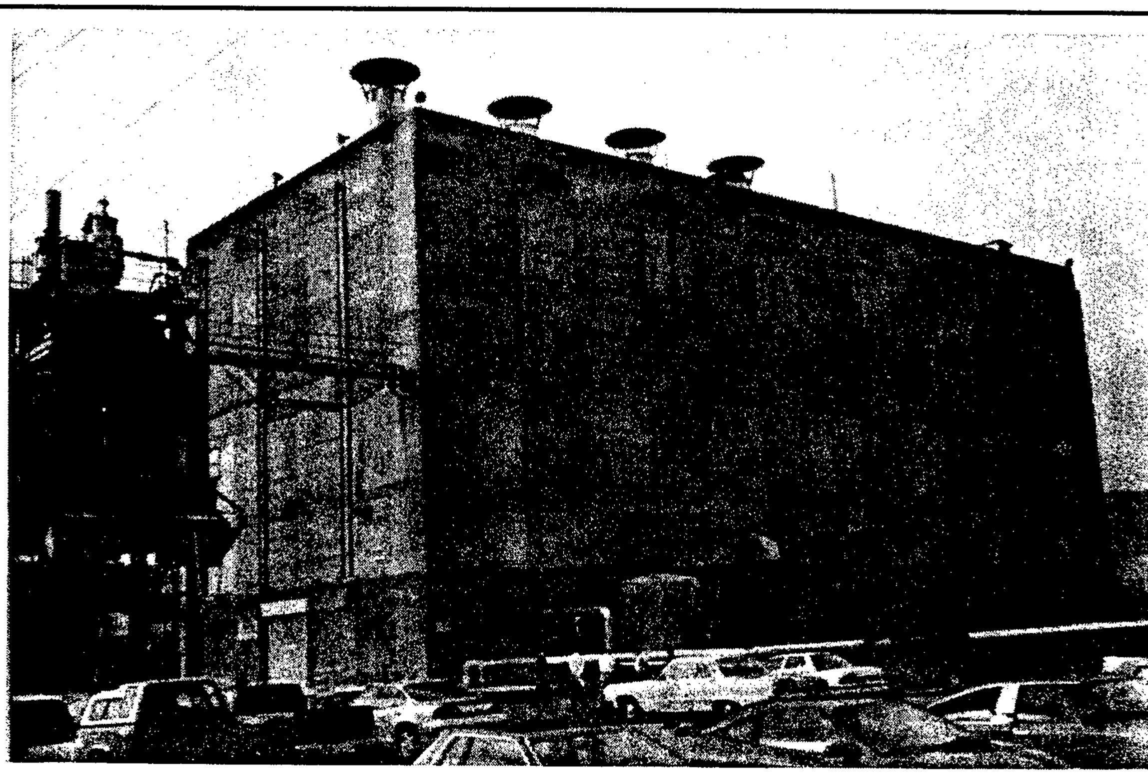

Figure 4. Building 2765 boiler plant.

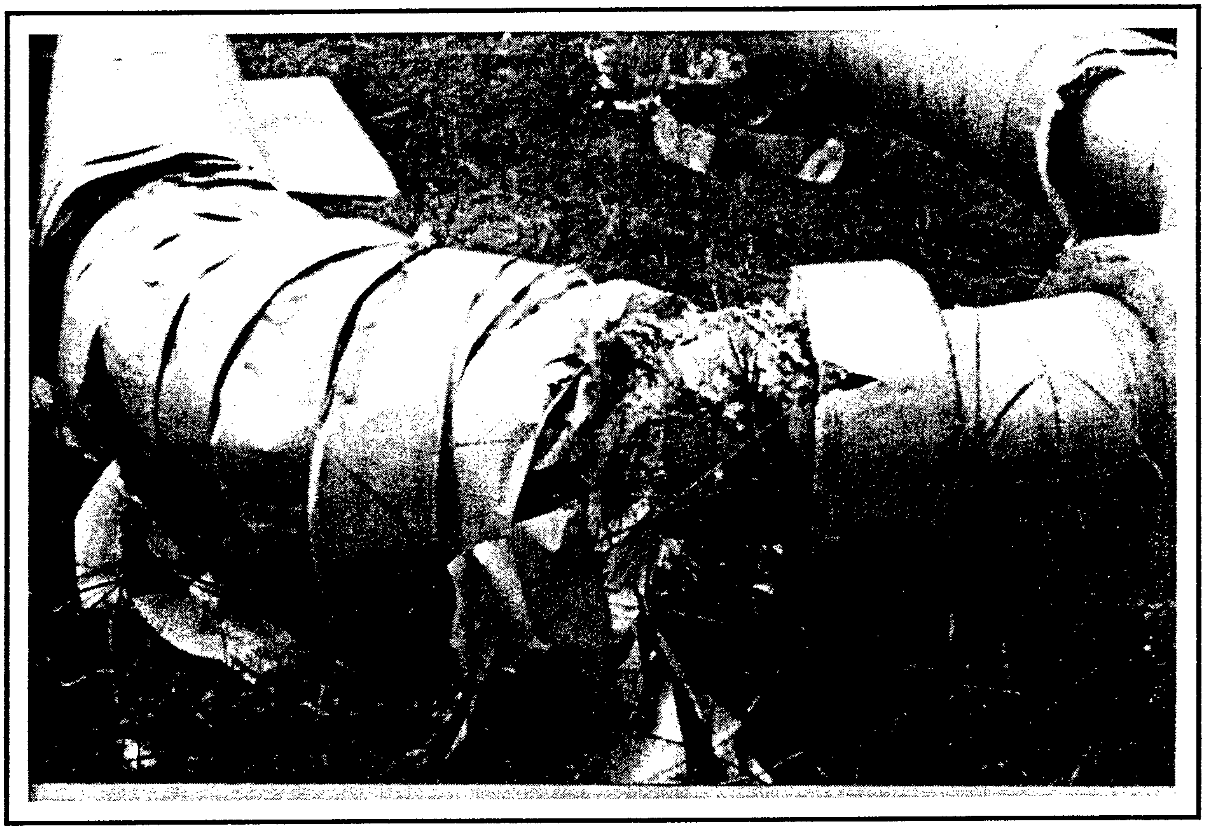

Figure 5. Steam distribution piping insulation and sheathing in poor condition.

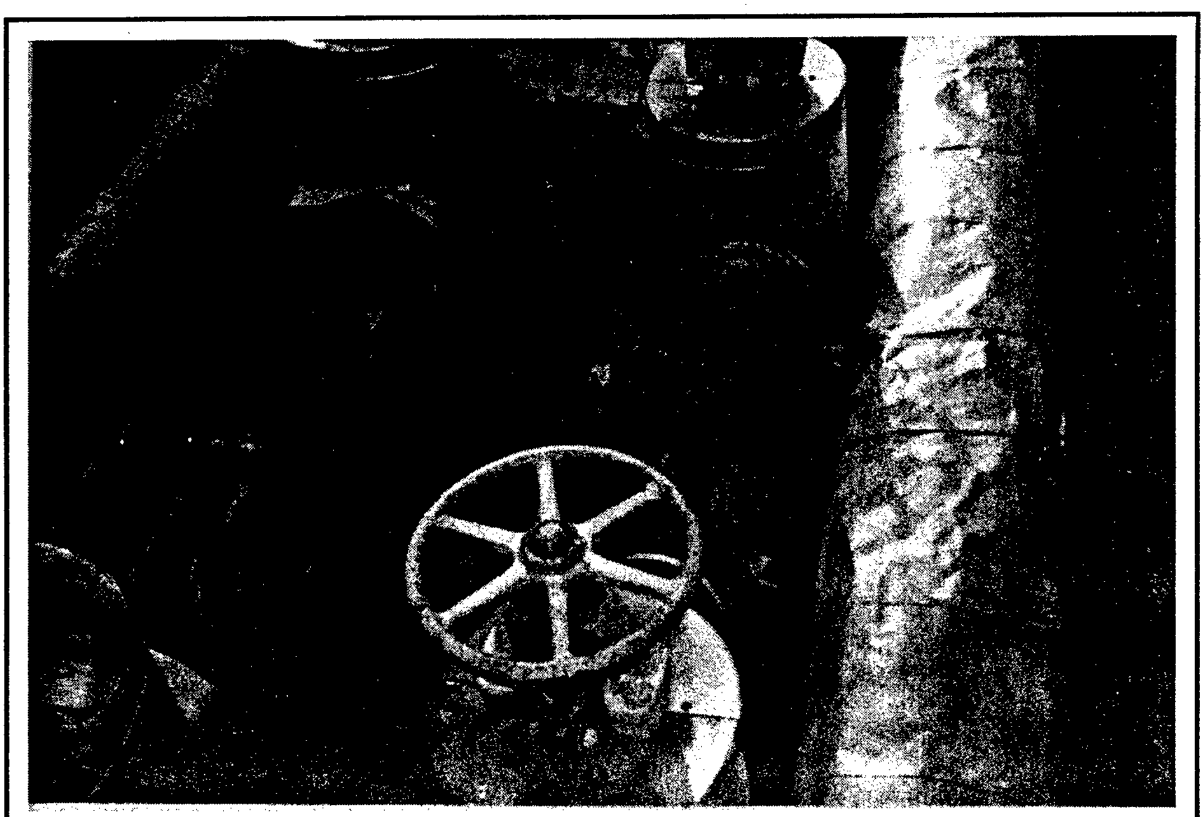

Figure 6. View of Redstone Arsenal valve pit.

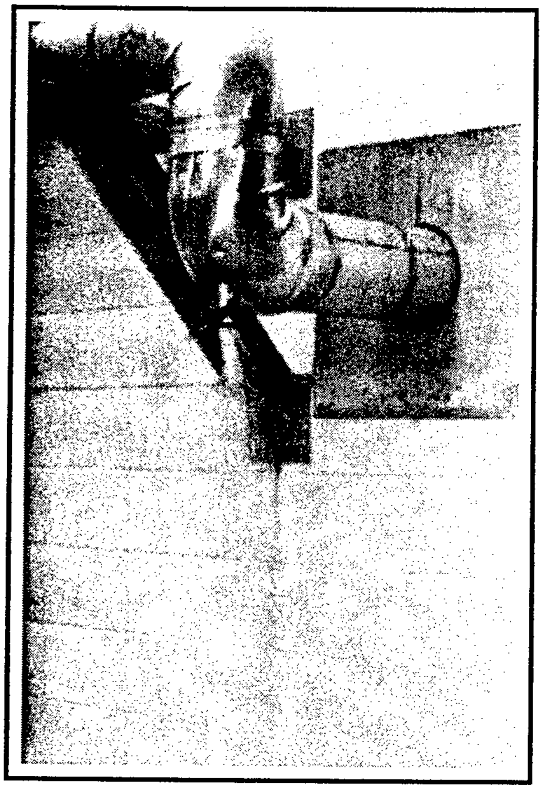

Figure 7. Condensate drain and sampling point located at Building 3628.

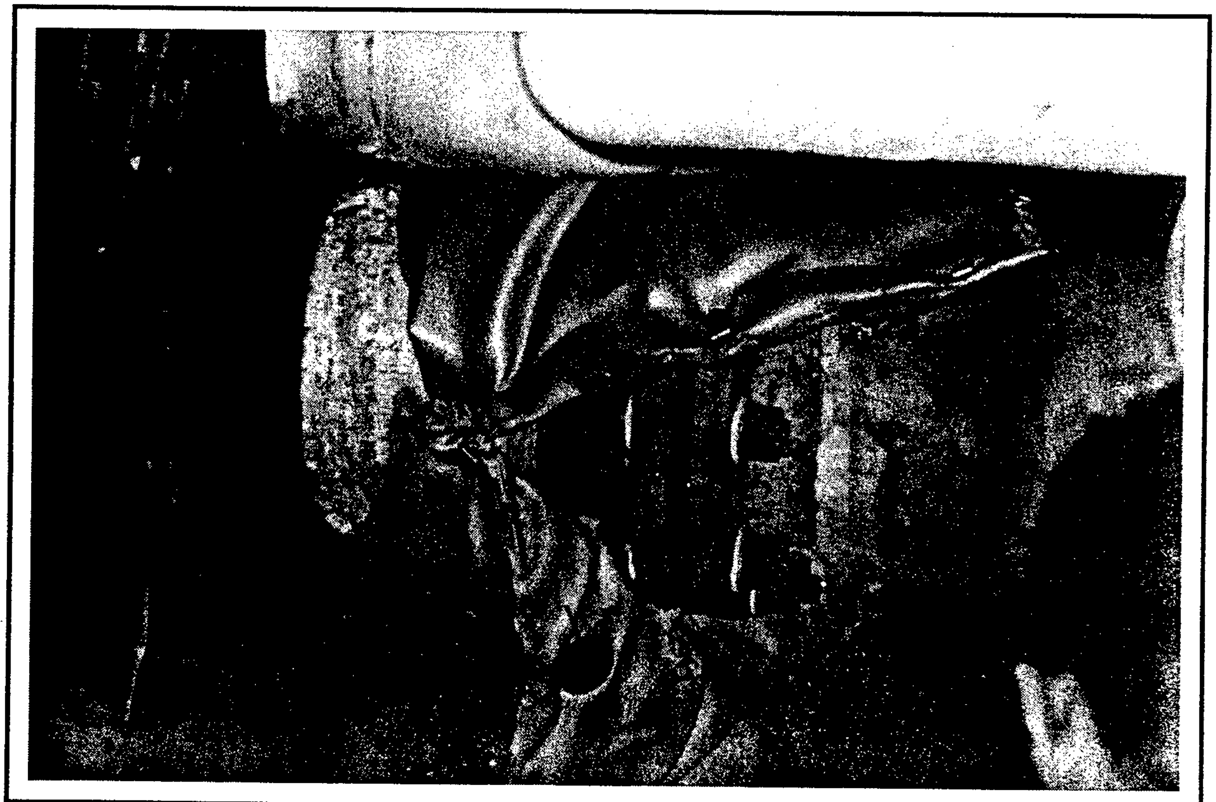

Figure 8. Steam and condensate piping in a common conduit.

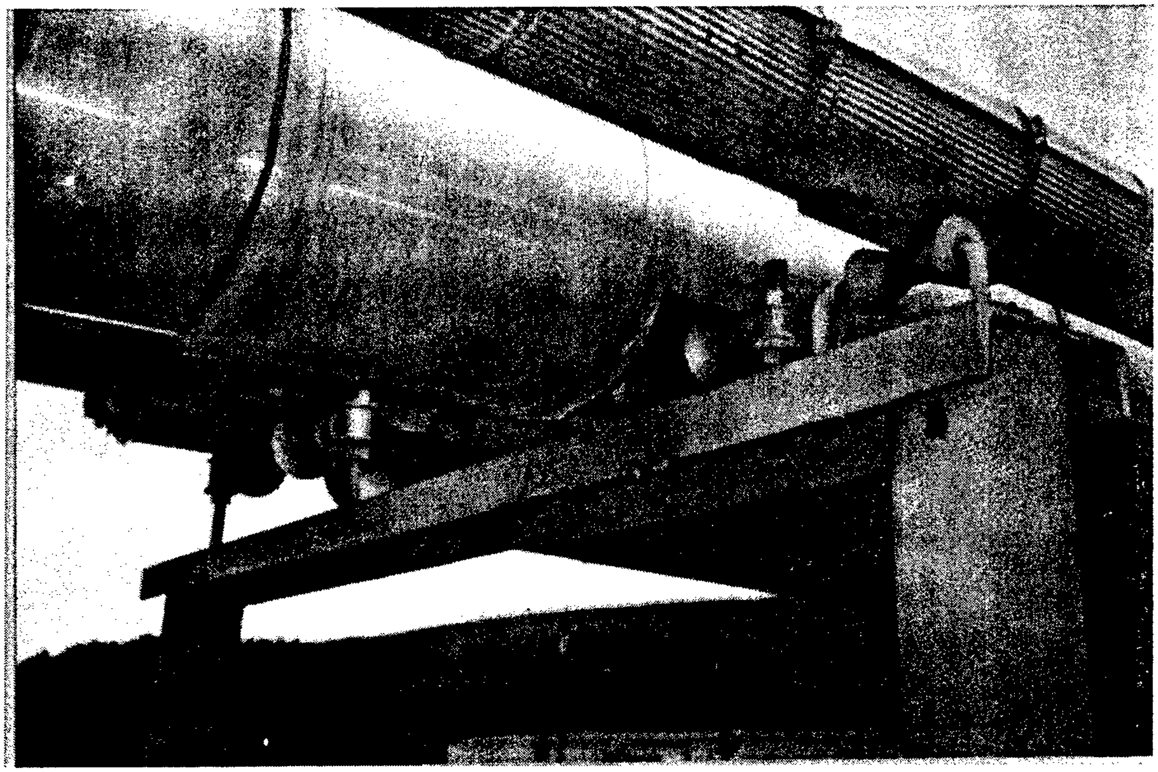

Figure 9. Distribution lines near point "b."

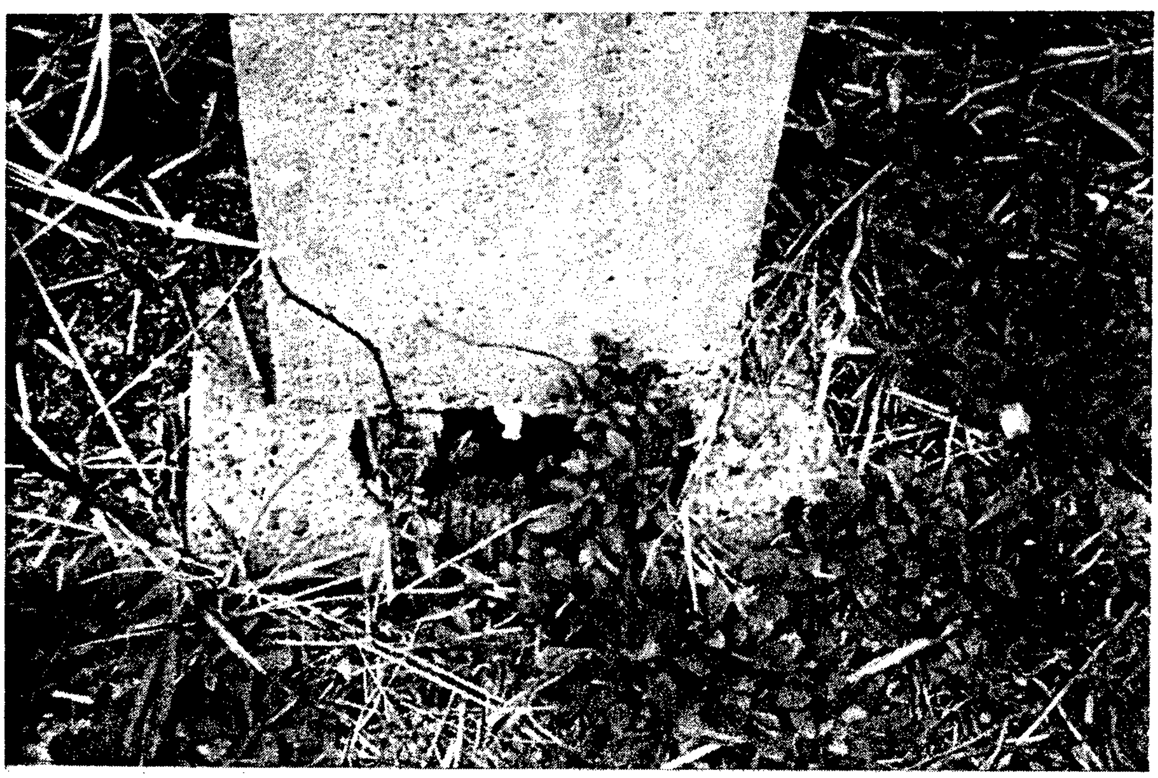

Figure 10. Piping support bearing problem.

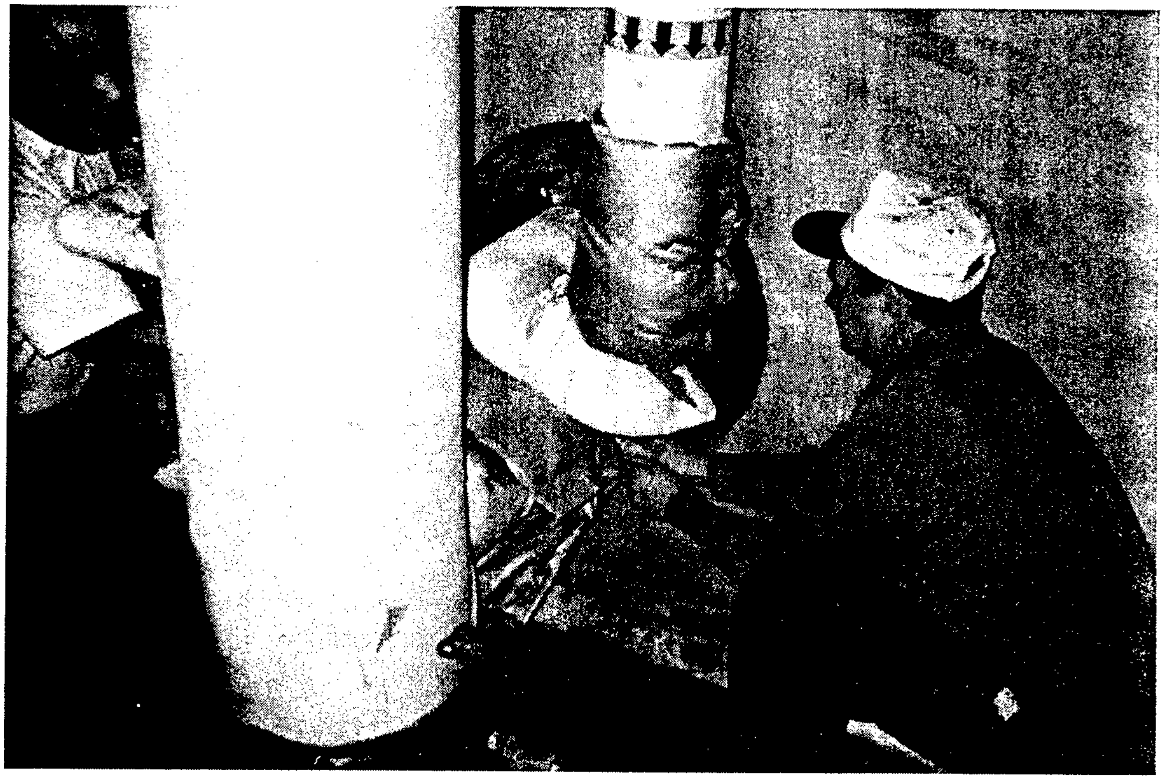

Figure 11. Entry point for steam supply for the Sparkman Center.

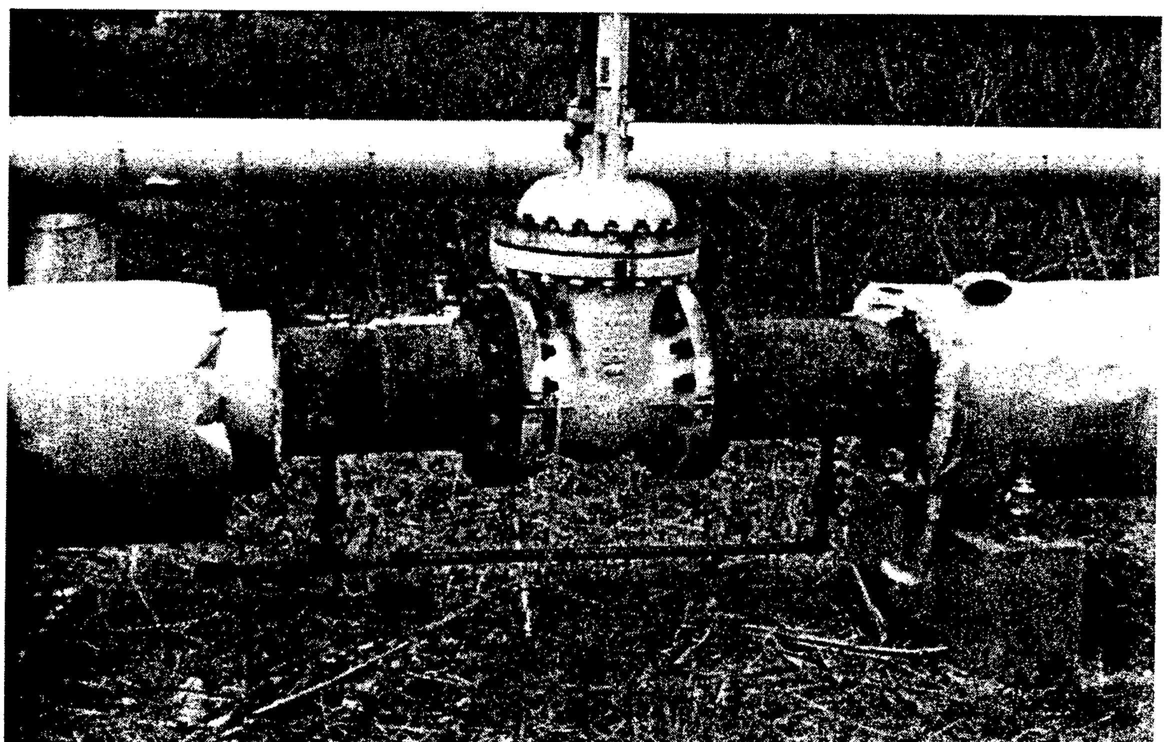

Figure 12. Distribution point "c" with startup bypass.

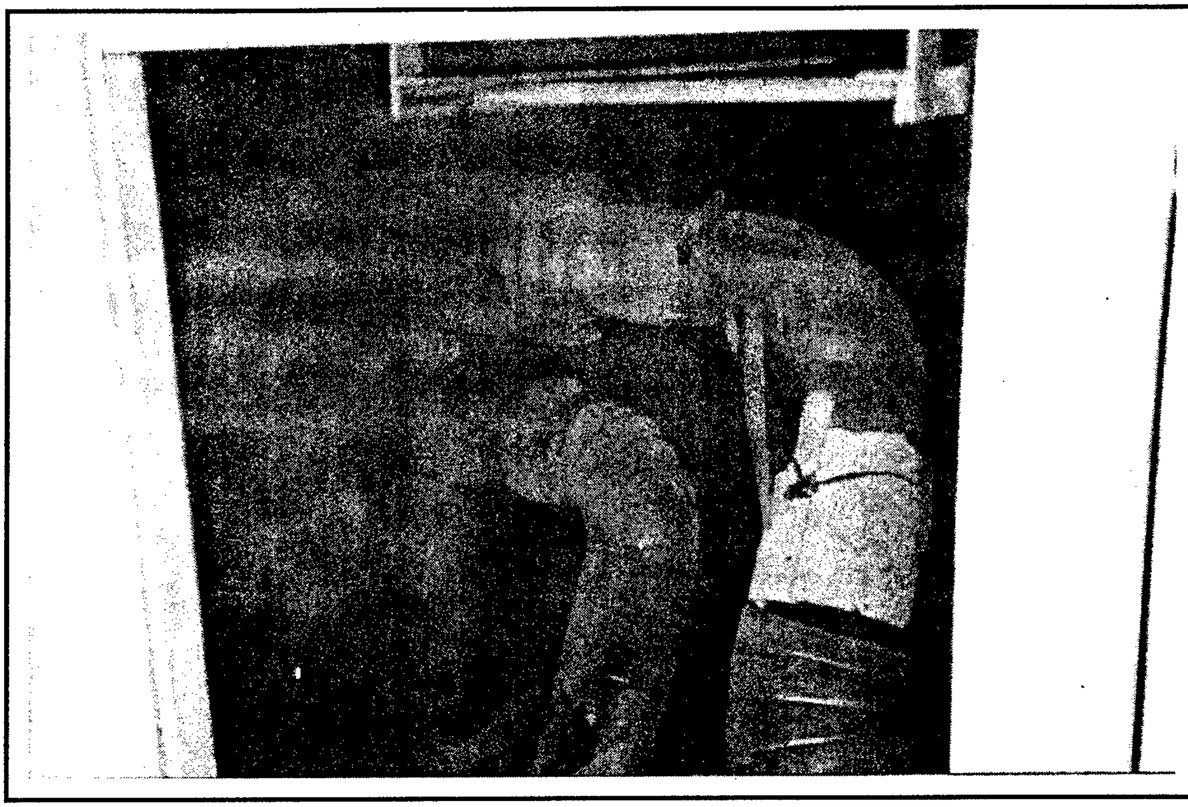

Figure 13. Steaming from distribution system manhole.

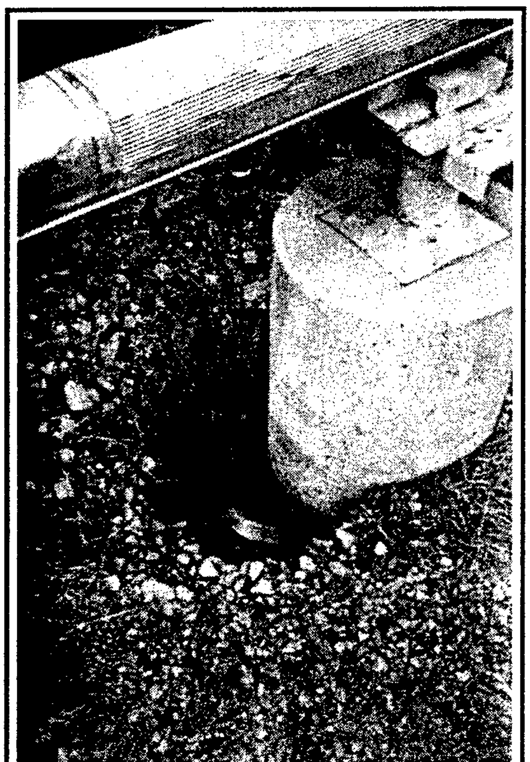

Figure 14. Soil erosion near piping support caused by a leaking valve.

Figure 15. Fire ant colony located near heat distribution system piping.

It would be possible to use the existing steam lines to pump hot water. In this case, the supply piping would be oversized. Pumping costs would also be less than same costs using smaller pipe, providing that LTHW can be pumped at these kinds of distances. Moving a given mass (and associated thermal content) relatively slowly results in less frictional losses than moving the same mass more quickly. The condition of the steam piping should be evaluated to ensure that it is in good condition.

Another possibility is a three-stage operation. First, the steam would quickly be converted to high temperature hot water. The high temperature hot water would traverse most of the distance. Then, in the local areas being served, the steam would be converted to low-temperature hot water and distributed. The additional conversions would add to the cost of the system. Also, this system might be unable to back feed—depending on design. If the low temperature portions are buried, a looped system (with sufficient valving) should be considered.

Whatever option is used, the expense of new heat exchangers should be anticipated.

Researchers identified some design problems associated with the steam and condensate piping for the Sparkman Center. Both the steam supply and condensate return lines are located in a single, common conduit. This practice has not been allowed according to criteria for at least 15 years. The reason for this is that, on average, military installations do not always consistently perform effective internal pipe corrosion control through the use of water treatment chemicals. Since untreated liquid condensate is inherently more corrosive to steel than steam, after a number of years of service, the typical result is that the condensate line begins to leak. The presence of water within the conduit then serves to further degrade insulation, which increases the ambient temperature within the conduit. Increased heat loss also results. As the process continues, low-pressure steam is produced. This steam often can be seen rising out of the higher end of the conduit. This steaming indicates ongoing, accelerated degradation and should not be ignored or allowed to persist. Within the conduit, the elevated temperatures in combination with the presence of water serves to accelerate corrosive degradation on the outside of the carrier piping. This further degrades the condensate piping and will lead to leaks in the steam supply piping.

Note that the condensate return line is located above the steam supply line. In some cases, the conduit itself has been sealed and used as a container for steam. This practice is strongly discouraged. The conduit piping is inherently inadequate for that application. Explosions could result. Another design error identified was the exceedingly long run of buried piping without a manhole. Current criteria limit the maximum length of buried pipe between manholes to 500 ft. Leak location and repair require more time, effort, and expense with longer runs.

To proactively mitigate this potential problem, the base should first closely and consistently monitor the chemical water treatment. For the Sparkman Center, specifically, the base should monitor the conduit vent on the high end and the conduit drain on the low end in the equipment room. An elbow should be added to the conduit vent on the high end now to prevent steam from blowing directly onto other piping and insulation. When a problem is observed, the first option should be perform a repair. If no treatment chemicals are found in the drained water, then the water source is likely to be groundwater. A conduit air pressure test can also be useful in determining conduit integrity. A second option is to not return condensate so as to preserve the steam supply line.

3 Fort Carson Analysis

Site Visit at Fort Carson, CO

The FY00 Utility Modernization Program Support Team met with the Fort Carson Directorate of Public Works from 23-24 February 1999. Fort Carson informed the attendees about an announcement in the Commerce Business Daily (CBD) on Friday, 26 February 99 about a privatization initiative on electric and natural gas utilities, although the Request for Proposal (RFP) does not address modernization.

CERL researchers explained to the Director of Public Works about the HEATMAP analyses conducted for Fort Carson. The HEATMAP analyses cover nine major alternatives with 18 different combination scenarios. One scenario is based on replacing in kind up to one-half of the entire high temperature hot water (HTHW) system associated with Boiler Plant 1860 over the next 2 years. A cooling system analysis was also conducted due to the presence of absorption chillers.

Another scenario involves abandoning the entire HTHW distribution system and installing a gas distribution system, decentralized hot water boilers, and small electric chillers. According to CERL researchers, the decentralized option is not competitive. The key advantage of keeping HTHW is the ability to control electric demand and to use inexpensive gas to cool. During 1997-1998, only 0.5 percent of the fuel burned at Boiler Plant 1860 was #2 diesel oil, which in turn allowed Fort Carson to minimize the capacity charge for gas deliveries to the post. Fort Carson has both interruptible and firm rates for natural gas. In a response to a question asked by the Director of Public Works, CERL researchers recommended repairing up to half the HTHW distribution system. CERL also mentioned that Airborne Data Systems, Inc. conducts energy surveys on electric and gas utilities. An infrared survey would need to be conducted to verify the condition of the HTHW system for the next 10 to 20 years. CRREL had conducted an infrared survey of the Fort Carson HTHW system prior to the site visit and provided results to CERL for inclusion in the analysis.

Overall, the results of CRREL survey showed the system to be in reasonably good condition considering its age. A CRREL infrared survey identified the sec-

tions of piping most in need of repair. With the distribution system being drainable/dryable, CERL suggested that other ways to assess the system would be by: (1) internal corrosion testing, (2) checking the internal pressure in the conduits, or (3) doing inspection digs at the most corrosive sites to observe the condition of the conduit exterior. CERL suggested using a shallow trench as opposed to direct buried piping.

Fort Carson Public Works staff helped provide the team with a tour of the central heating plant (Building 1860), which supplies 150 buildings on post. The plant contains three 40 MBtu forced circulation high temperature hot water (HTHW) boilers. Two of these were manufactured by Union Iron Works and the other by Flow Control. A closed system sample was gathered from the plant to use for analysis. The results of the analysis are listed in Table 2. The team also viewed distribution lines at one manhole pit by Building 1350 and one manhole pit near Building 1047. The north end of Building 1047 includes a mechanical room that supplies domestic hot water to the whole barracks. Within the mechanical room of Building 1047, the team viewed water heat tanks, heat exchangers, and sumps. The other side of the building contains chilled water pumps. The team also went to view two manholes located near Building 1954 (Barracks of the 3rd Battalion, 29th FA) with piping distributed under the sidewalk.

Table 2. Fort Carson water chemistry data.

Parameter	Closed System Sample from Plant
pH	10.14
Temperature (°F)	74.84
Chloride (mg/L)	12.00
Copper (mg/L)	0.01
Iron (mg/L)	0.00
Sulfate (mg/L)	141.00
Sulfite (mg/L)	2.00
Total Dissolved Solids (mg/L)	198.00
Total Hardness (mg/L)	1.00
Methyl Orange Alkalinity (mg/L)	72.00
Phenolphthalein Alkalinity (mg/L)	30.00
Conductivity (μmhos/cm)	578.00

Observations from Fort Carson Site Visit

Overall, the direct buried high temperature hot water system seemed to be performing well. Based on the pipe sample from a manhole repair shown to the team in the boiler plant, the water treatment appears to have been well maintained. The sample showed essentially no internal corrosion. There was no evidence of burnt grass and only a few steaming manholes. However, given the age of the system, coupled with the fact that most of Fort Carson has been determined to have moderate to severely corrosive soil further tests are warranted. In particular, some simple tests should be conducted in those sections intended for continued use.

1. Open conduit drains at the low end. If any water comes out, take a sample to be tested for the presence of treatment chemicals. The drain plug should be replaced with either a brass or bronze plug.
2. Perform a conduit pressure test. Seal the conduit annular space and pressurize to 15 psi. Valve off the conduit with a pressure gauge in the system and see if the conduit holds pressure. If more then 2 pounds of pressure are lost in an hour then the conduit does not have integrity. If the pressure rises then there is likely a carrier leak and the conduit should not remain sealed.

The CRREL infrared survey of Fort Carson also provided some quantitative results that could be used in prioritizing replacements.

Note that variations in depth of bury, soil properties, and the ability for leak effects to migrate within the conduit annular space will affect the results. With Fort Carson's relatively low rate for natural gas, energy efficiency alone is not as strong of a motivation compared to Army installations in general. A detailed look at where leaks occur and their frequency would also be useful information. Another suggestion would be to dig an inspection pit to look at the surface of the conduit piping to see what degradation effects can be observed directly.

Fort Carson DPW indicated that the installation has a cathodic protection system — a sacrificial anode system instead of an system. Researchers requested details of the original design. Further investigation as to the current effectiveness of the cathodic protection system would be useful. If the system is still in place and working effectively, then the corrosive degradation of the outer conduit surface should be minimal. Note that sacrificial anode systems are simpler to maintain and have a higher probability of remaining functional over long periods than impressed current systems, presuming that the original design life has not been exceeded and that the anodes have been consumed.

Army Regulation 420-49 (Utility Services, 28 April 1997) requires that serious consideration be given to first using aboveground system piping, then, second to using a concrete shallow trench for any replacement work. The third and least desirable distribution design type is to use direct buried conduit piping. Some exceptions are allowed, but this preferred order of preference is based on the Army's wide experience.

The existing manholes, though of an older design, seem to be in good shape and should be considered for incorporation into any new construction where applicable. Note that, if this option is chosen, then the existing manholes should be modified by adding a raised top with screened sides (refer to TM 5-810-17). USACE Omaha District is credited for the raised top manhole design execution, based on a design concept from N.M.D. & Associates, Inc.*

Of the few manholes examined there was one exception (in front of the barracks with the loud speakers on top) where the structural integrity of the concrete cover might be in doubt (Figure 16). It appeared that construction consisted of placing a corrugated metal plate across the span and then pouring concrete on top. It is unknown if any reinforcing bar was employed. It now appears that the corrugated metal plate is seriously corroded with sections of scale dropping on the piping and manhole floor. The 2-in. by 4-in. wooden supports observed (Figure 17) are a temporary fix at best. If in fact the corrugated metal plate is an essential structural element of the design, then structural integrity may be compromised. (The cracks in the concrete cover may or may not be related.)

Of all the manholes examined, investigators found only gravity fed manhole drains connected to storm drains with backflow preventers. Only one manhole had water in it, which might indicate a clogged drain.

Several design deficiencies merit correction. The most dangerous were valves on vent piping (Figure 18). If a conduit is completely sealed off and there is a carrier leak, a dangerous situation can occur. The conduit piping is not designed to hold high pressures. The conduit vents should also be redone so as to not be manifolded together. Manifolding allows for a failure in one conduit to be transmitted into the next. In addition, the vent piping should be brought above grade so that any problems can be seen and corrected.

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* N.M.D. & Associates, 2001 Paul Springs Parkway, Alexandria, VA 22308.

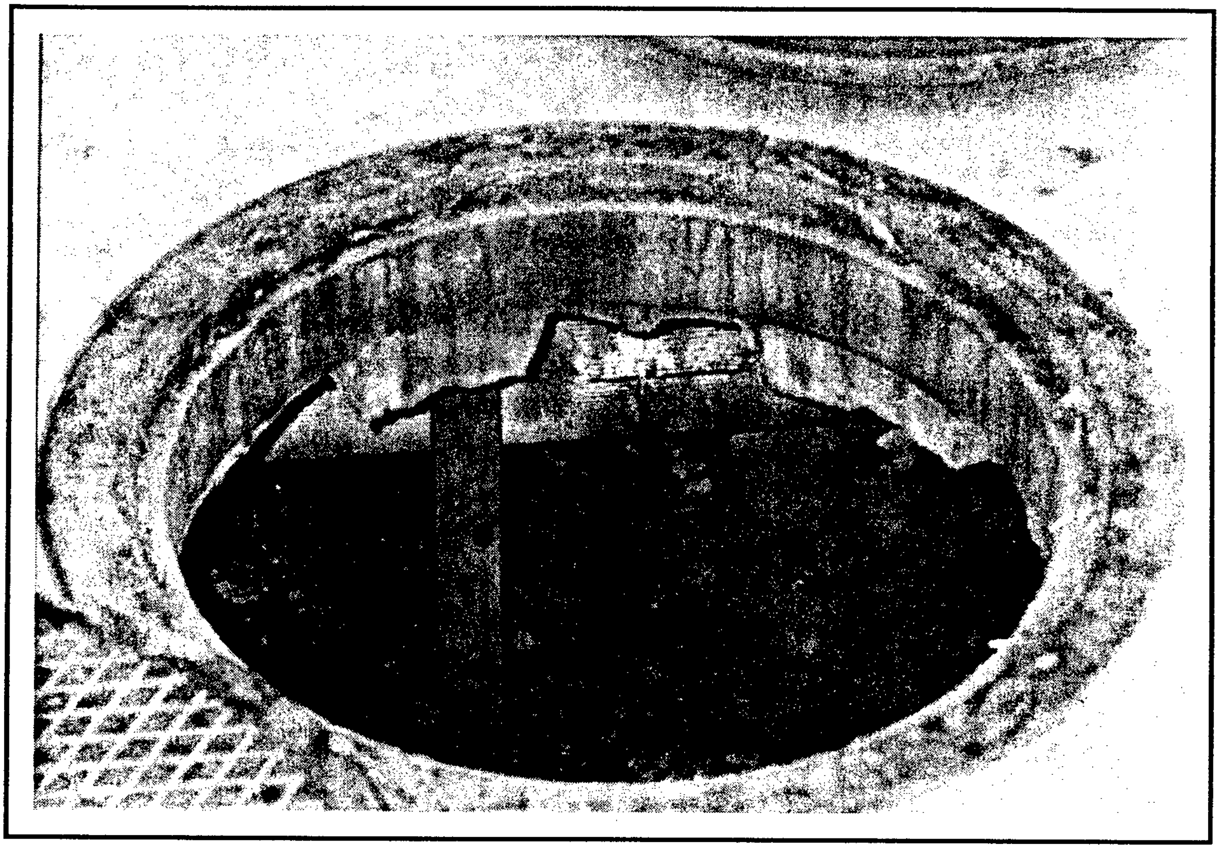

Figure 16. Manhole with corrugated metal plate.

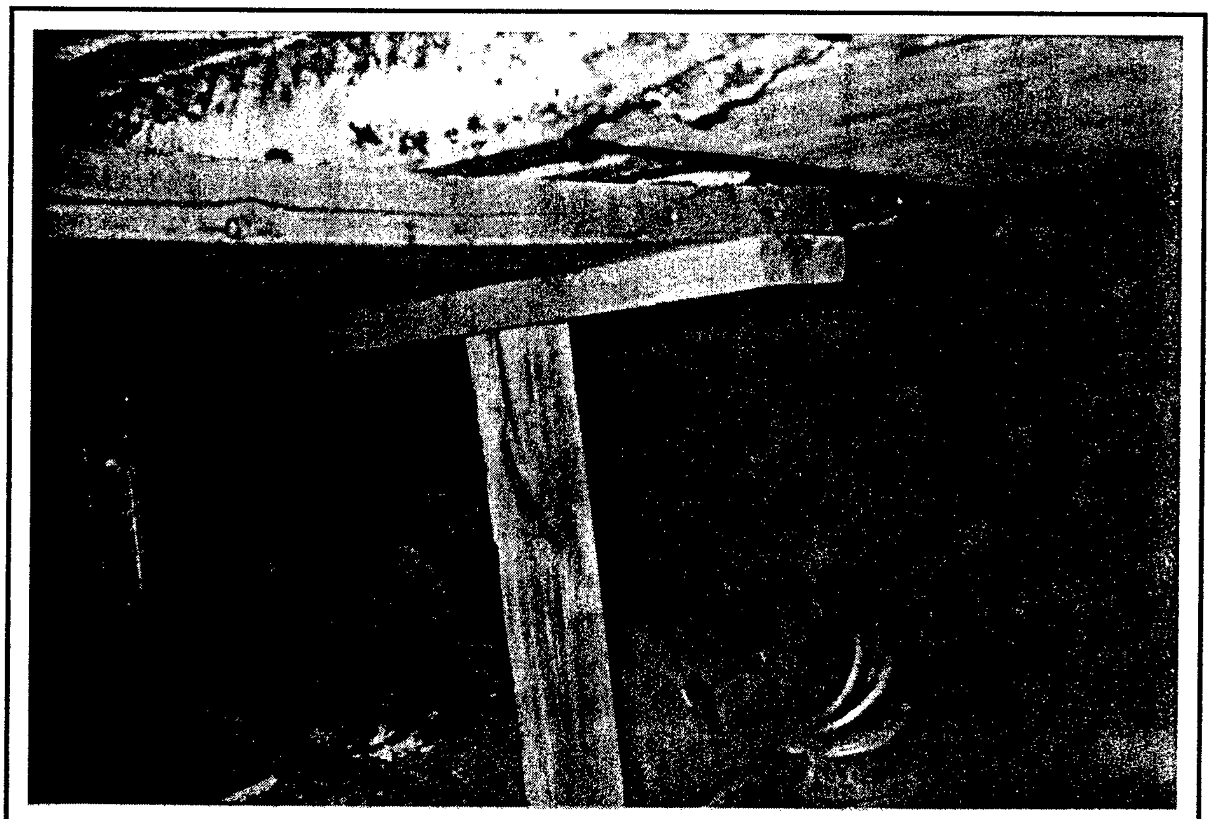

Figure 17. Temporary supports for manhole.

Figure 18. Corrosion scale and valved conduit in valve pit area.

4 Fort Gordon Analysis

Site Visit at Fort Gordon, GA

The FY01/02 Utility Modernization Program Support Team met with the Fort Gordon Directorate of Public Works in Building 14600 on 22-23 March 1999. According to Fort Gordon, the project is a great window of opportunity for the next 25 years. The major issue right now is locating funding for design. The high temperature water (HTW) distribution in the shallow trench is in good condition. The chilled water system in Plant 25330 is 30 years old, and Plant 25910 has a 25-year old chilled water system with significant leakage problems. In the mid-1980s, electric centrifugal chillers replaced the steam turbine and absorber systems. Direct-fired water boilers replaced high-pressure steam boilers. Plant 25910 has some amount of asbestos on the chilled waterside. The meter in the makeup water shows 60,000 to 70,000 gal per day. Plant 25910 on the north side supplies 5500 tons of cooling to the barracks and training facilities, while Plant 25330 on the south side supplies 2000 tons of cooling to the hospital.

Energy consumption is continuously monitored as the information comes from various sites throughout the base. Georgia Power supplies electricity at a real-time price structure, with prices monitored hourly to determine peak shaving. Their 9 MW peaking plant has provided a dollar savings for the Army ($400 to $500K a year credit), and is government owned, government operated (GOGO). Georgia Power is not currently moving toward deregulation. Natural gas, however, is under deregulation.

Fort Gordon has led TRADOC installations in meeting or exceeding 1985 baseline energy consumption goals. Fort Gordon's energy management strategy consists of a three-pronged approach of technology improvements, low-cost/no-cost initiatives, and command support. Fort Gordon has successfully competed for Energy Conservation Investment Program (ECIP) and FEMP funding to execute energy conservation projects. Fort Gordon also stated that two existing chillers in Plant 25330 were replaced with energy-efficient chillers with reduced capacity. Energy studies and TASK analyses have been conducted to examine the entire system. The TASK program defines the number of miles of the distribution system. Lighting retrofits were accomplished through Installation Support Cen-

ter (ISC) contracts. Energy savings from the lighting retrofits will pay for the project.

In terms of environmental requirements, the main issue, according to Fort Gordon, is fuel storage. There are currently 400,000 gal of fuel capacity stored in underground tanks serving as backup for natural gas. The tanks would have to be added to Fort Gordon's scope of work. *Means Cost Data* was used as the primary source for pricing out storage tanks and manifolding valves.

The team had the opportunity to view a computer database showing real-time KW costs per hour provided by Georgia Power, with rates given an hour advanced notice. The team also viewed the Utility Monitoring and Control System (UMCS) that monitors the heating and cooling plants 24 hours a day.

The team traveled to the heating and cooling plant (Building 25910, shown in Figure 19). Centralized heating and cooling is supplied to barracks, administration, and training facilities. There are a total of eight #2 fuel oil tanks – two 50,000 gal tanks on the north end, two 50,000 gal tanks on the east end, and four 50,000 gal tanks on the south end. A base contractor runs the plants. A piping replacement project was underway during the time of the site visit. There are five Erie City Iron Works boilers that were originally coal fired and now use oil or gas. Figure 20 shows one of the boilers. All five boilers will be replaced with three hot water (HW) generators. The chillers (Figure 21) will be replaced with a mix of chillers to adequately meet the load. Currently, there is over 6300 tons of cooling capacity. According to the Fort Gordon energy study, the existing chilled water distribution pumps will remain in operation, but the drives will now be controlled by variable speed drives. The free cooling system will operate primarily in the wintertime, and will use cooling towers only to obtain chilled water to be stored at 42 °F. Cooling towers would be replaced, with the resized cooling towers manifolded to each chiller. Water treatment would also be considered.

The team returned to Building 14600. Fort Gordon provided the team copies of the energy study for the heating and cooling plants. Fort Gordon is looking at the cost estimates based on when the study was performed 2 years ago. The project costs are not escalated in the 2-year old study, but only in the SUPER and TASK analyses. The plant study needs to be updated, based on load. Fort Gordon explained that the command has changed within the last 2 years, and the reality of funding has also changed. According to the TASK analysis, the chilled water distribution is 77,000 linear feet (approximately 15 miles). Fort Gordon is also looking at alternatives between decentralizing hot water and shutting down the HW generators during the summer.

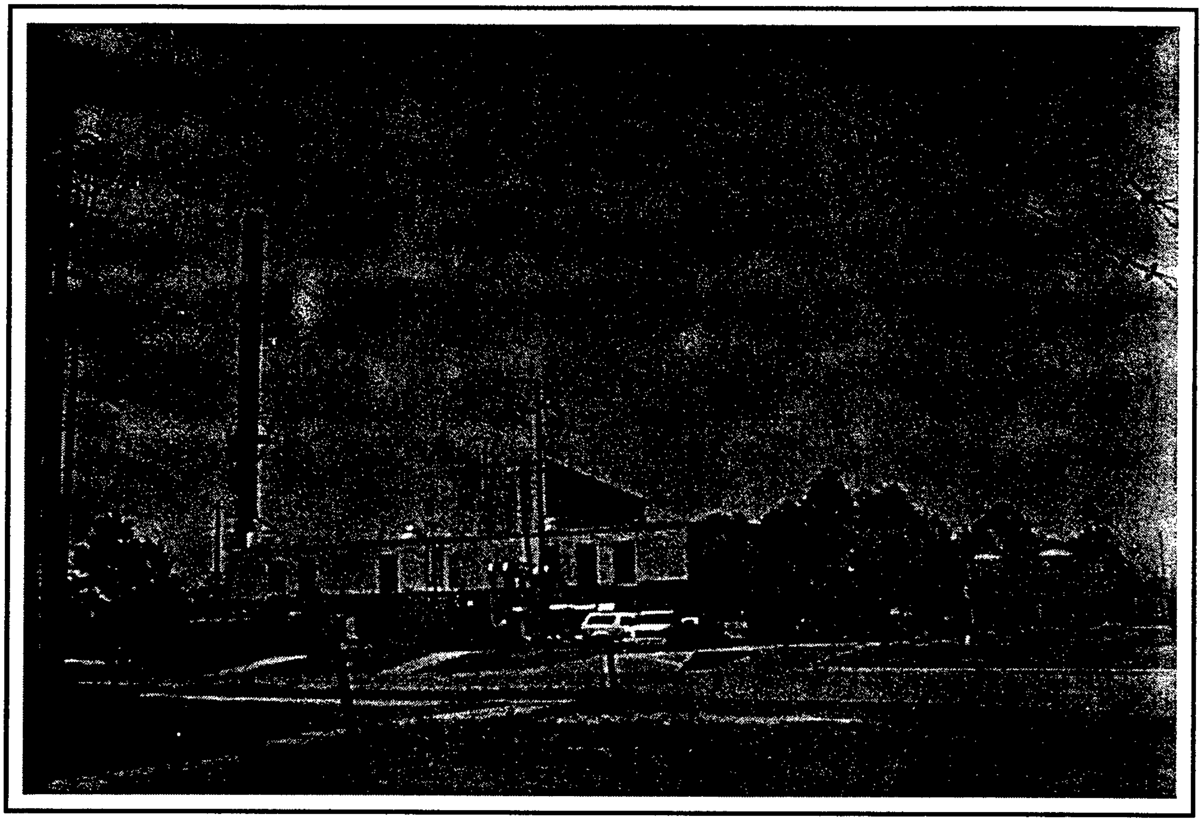

Figure 19. Fort Gordon heating and cooling plant (Building 25910).

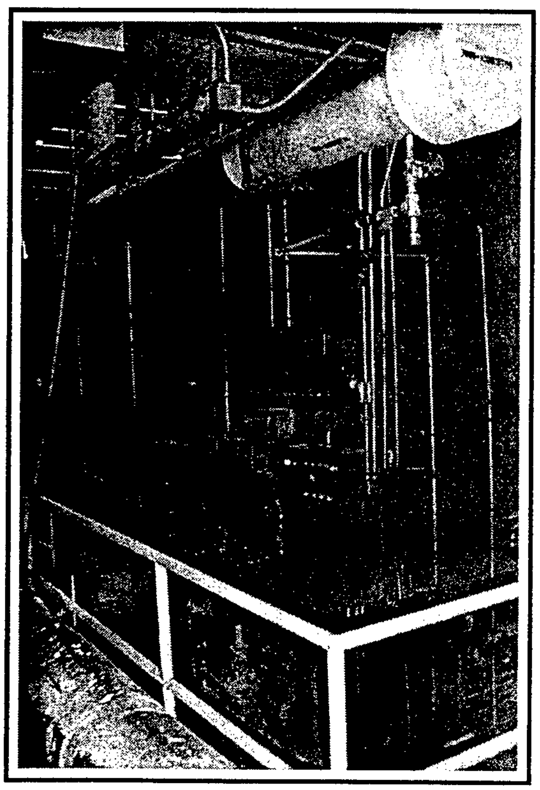

Figure 20. Erie City Iron Works boiler in Building 25910.

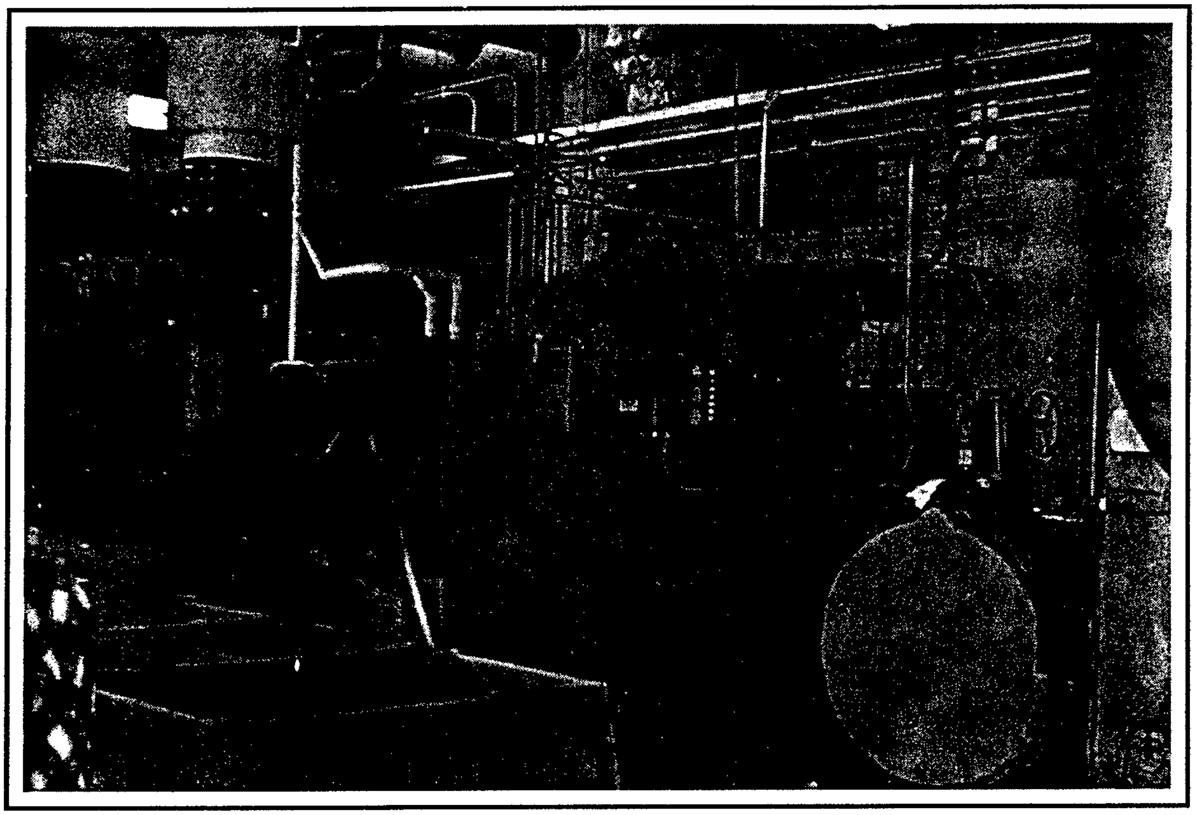

Figure 21. Chiller in Building 25910.

The team traveled to the second heating and cooling plant (Building 25330). The cooling plant (Figure 22) has approximately 2000 tons of cooling capacity. The chillers use R-123 refrigerant. The plant is operated manually, with maintenance personnel on shift. According to the Fort Gordon energy study, there is no need for the free cooling heat exchanger due to winter shutdown. Improving the efficiencies could reduce the energy baseline based on 1994 data. According to the Fort Gordon energy study, there are two steam generated boilers that will be replaced with hot water generators operating in a primary loop circulating HTW to the load via variable speed pumping. Chemical water treatment will be included in the scope of the project.

Observations from Fort Gordon Site Visit

The heat distribution system at Fort Gordon has been replaced in increments over the last few years with shallow trench. Therefore the utilities modernization effort will not include any significant heat distribution piping. The supply temperature of the HTHW systems has been reduced from its former level of about 385 °F to around 300 °F without any difficulties being encountered.

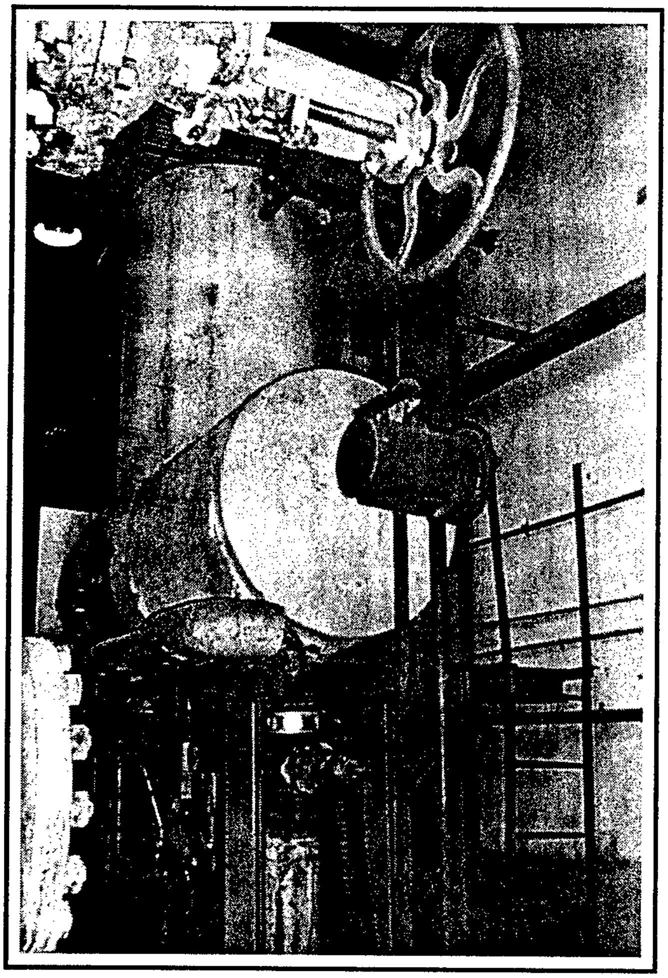

Figure 22. Inside chiller plant (Building 25330).

CRREL encouraged the base to pursue even further supply temperature reductions and lower return temperatures as much as possible through better management of control valves. Variable speed pumping is being considered as part of the utility modernization efforts. This will certainly help reduce return temperatures (increase delta T) resulting in lower heat losses as well as reduced pumping energy.

The condition of the chilled water system is not as good as that of the heat distribution. The chilled water (CHW) system is over 30 years old. No major replacements have been accomplished. The system is buried up to 20 ft in depth. This, coupled with the native sandy soil, makes it difficult to locate leaks. In July 1998, the CRREL infrared survey team attempted to find the leaks in the Fort Gordon systems. It is difficult to locate chilled water leaks by infrared due to the low temperature differential between the chilled water and the surrounding soil. The sandy soil permits leaking chilled water to quickly drain below the piping rather than to manifest itself at the surface. Currently, leakage rates were reported to be up to 60,000 to 70,000 gal/day. It is believed that the system

is insulated and consists of steel carrier pipes and some asbestos cement carrier pipes. It was not feasible to verify the condition of the system. CRREL looked in one manhole, where it was dry, and pipes had intact insulation. There was no one available that knew any specifics about the system. Based on the age of the system, current leakage rates, and the burial depth, it would seem that replacement would not be warranted.

CRREL's recommendations for the chilled water replacement would be to keep the new lines as shallow as possible given expected wheel loads and danger from damage during construction of other utilities, probably around 2-3 ft. The decision on insulation should be based on the heat loss calculations, both with respect to life cycle cost effectiveness and maximum permissible temperature increase in transport. The equations in Chapter 11 of the *1996 ASHRAE Systems and Equipment Handbook* should be used, along with appropriate soil temperatures as estimated using the formulas available on CRREL's web site at http://www.crrel.usace.army.mil/ard/cegs02695.htm. A number of options are available for the carrier piping including welded steel, ductile iron, PVC, or possibly even HDPE (high density polyethylene). CRREL would recommend welded steel insulated with polyurethane foam insulation and jacketed with HDPE. Particular attention should be paid to the field joint insulation and jacket closure method, as chilled water lines will tend to attract moisture from the surrounding soil when in operation. With proper water treatment such a system should function efficiently for many years.

5 Fort Stewart Analysis

Site Visit at Fort Stewart, GA

The FY01 Utility Modernization Program Support Team met with the Fort Stewart Directorate of Public Works in Building 1101 on 24-25 March 99. Within the past 6 months since the site visit, 13,000 to 14,000 gal per day of makeup water were generated; this indicates major leakage. The high temperature hot water (HTHW) distribution piping is direct buried. Burnt grass shows signs of poor HTHW distribution system condition. Two 1500-ton centrifugal chillers with R-134 were installed in 1994 and 1995, respectively. There are currently problems with one of the chillers. There is one 1600-ton absorption chiller, and an 1100-ton absorption chiller. The latter chiller gives trouble constantly. A total of 5700 tons of chiller capacity serves three zones. Zone 1 has the most buildings and requires two direct variable frequency pumps at maximum speed during the summer. Zone 2 requires 2 pumps running during the summer. Zone 3 operates at all times and serves the hospital, which has its own chiller. The hot gas bypass was installed to run in the winter months. The boiler plant (Building 1412) has two 48,500 lb/hr dual-fired natural gas/#2 oil boilers (Boilers 1 and 2), and one 56,000 lb/hr dual-fired natural gas/#2 oil boiler (Boiler 3). The average monthly natural gas consumption is 1,500,000 cu ft of gas. The boilers are not in operation when the wood boiler (Boiler 4) is operable, except on peak demand days and during severe cold weather. The wood boiler operates at 95,000 lb/hr and is shut down every spring and October. Preheater tubes are occasionally cleaned due to sand and ash plugged in the tubes, causing obstruction of airflow through the boiler. A venturi is used to clean smoke. Water tubes are rotted out because of soot and mud plugged in the tubes. There is continuous repair on the wood chutes and wood handling equipment. Sawdust, chips, bark, sand, and sawmill residue are types of wood received by the tractor-trailer truck. The wood burning plant was implemented as an Energy Conservation Investment Program (ECIP) with a scheduled payback of 8 to 9 years.

Natural gas operates at an interruptible rate. The natural gas is deregulated, with an amount nominated a month in advance. Fort Stewart is penalized if gas is burned beyond what the base agrees to use, and also if no gas is burned. A propane air-mixing tank will cover makeup for natural gas. Fort Stewart does burn #2 fuel oil, which is easier but more expensive to use. Used oil in the

amount of 130,000 to 140,000 gal a year is saved for emergency purposes, and makes operating the wood boiler easier. The ash is given to the landfill on post.

A satellite plant is installed in the 4000-4500 block. Each building has a separate absorption chiller to maintain the cooling load. Steam is used to run the absorption chillers. There are two absorption chillers in the satellite plant, which are not operational. The chillers in the 4000 block provide chilled water.

Electricity at Fort Stewart has a summer demand of 30 MW and operates at a 95 percent ratchet charge. Fort Stewart is presently on a multiple load management rate with real time pricing. An estimated one-third of the demand goes to family housing. The Energy Monitoring and Control System (EMCS) is in operation in at least 60 buildings. Fort Stewart is looking at installing a number of turbine generators to generate electricity during high demand. It would be up to Fort Stewart's Energy Savings Performance Contractor (ESPC) to determine if this alternative is economical. Fort Stewart is also looking at recommissioning a number of their systems.

Currently, Fort Stewart cannot run the absorption chillers to cool Zones 1 and 2 due to the header extension. The natural gas-fired boilers need upgrading, and plans are being considered for installing another wood boiler. The DD1391 is being updated to include the addition of another wood boiler. There are currently no feedwater pumps. Feedwater pumps would require less maintenance and would cost around $30K to $40K each to install. Induced-draft fans for boilers would be needed to improve boiler efficiency. Only the wood boiler (Boiler 4) has an induced-draft fan. Another item not addressed in the DD1391 is the replacement of 3 boilers with 4 smaller boilers to extend the boiler life. An additional option that Fort Stewart is considering is to use a cascade heater to run the HTHW from the Central Energy Plant down to the 4000 block instead of steam to the satellite plant cascade. The cascade heater would run for half a year.

CRREL has already performed infrared (IR) studies on Fort Stewart's distribution system and requested to examine the distribution lines on their map to include missing information not previously covered on their last IR study. CERL commented that the energy density is the driver to determine whether the central plant is viable. A reference energy density of 0.7 MBtu/acre is the general rule of thumb. CERL also mentioned that the heat load per square foot would be just as adequate, without the need to run Building Loads Analysis and System Thermodynamics (BLAST) or Trane™ Air Conditioning Economics (TRACE) programs.

The team traveled to the area outside Building 410 (Woodruff Theater) to observe valve pits and distribution lines in Zone 3. Zone 3 was installed in 1983. The first valve pit showed casing corrosion (Figure 23). All HTHW lines are buried. The second valve pit was behind Building 411 (Library), with casings also perforated by corrosion (Figure 24). Pump problems have caused water to come back up. CRREL suggested that a storm drain would be needed to pump the water out to another location. The team also stopped by a raised vent point, which has no access to the conduit, but has a vent pipe coming up from the carrier pipe. The team also viewed the third valve pit by the athletic field. The Zone 3 distribution ends at the hospital plant. Outside Building 446, there were leaks in the fourth valve pit visited.

The team then traveled to the 600-700 block of barracks to observe distribution lines in Zone 1. Outside the 700 block, there are casing failures in a number of valve pits. A member of the Fort Stewart DPW staff mentioned that valves were in need of lubrication. In the 800 block, there are problems with heat every fall season. A booster pump may be the answer to the problem.

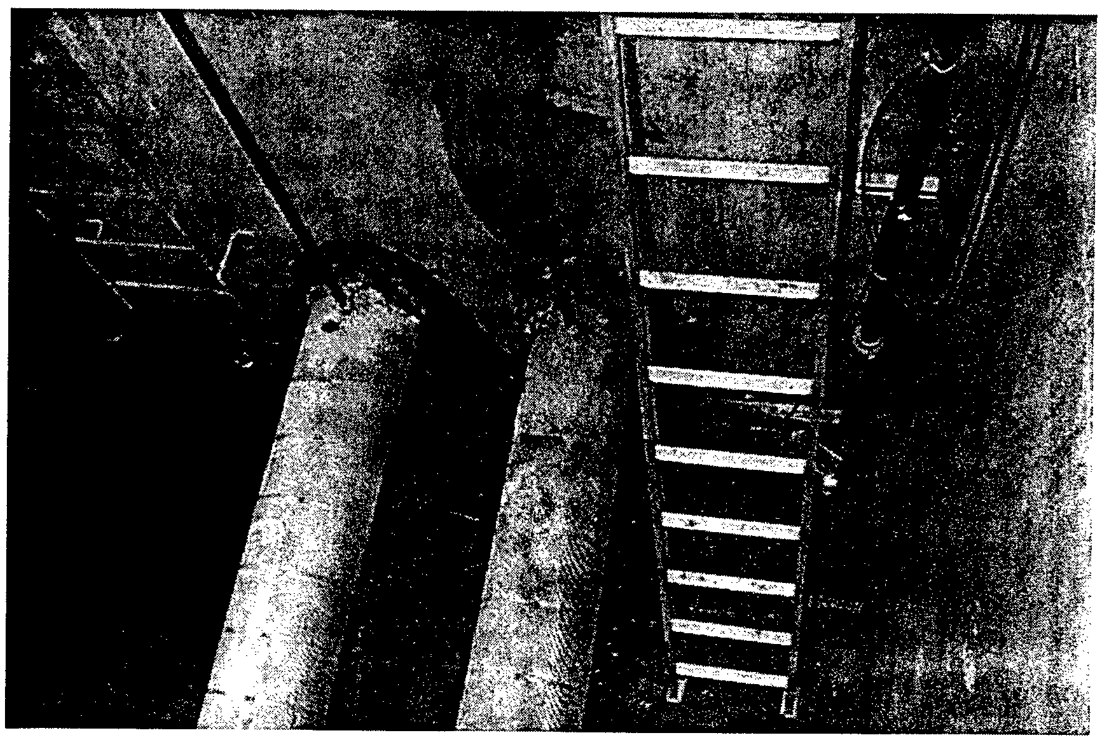

Figure 23. Casing corrosion of conduit at manhole wall penetration in Fort Stewart valve pit outside Building 410.

Figure 24. Casing corrosion in Fort Stewart valve pit outside Building 411.

The team visited the central plant (Building 1412), which has two 1465-ton Trane CentraVac R-123 water chillers (1 and 2), one 1600-ton Trane absorption cold generator, and one 1100-ton York absorption unit. Boilers 1 and 2 are Nebraska boilers with 48,500 lb/hr capacity at 230 psig (gauge pressure), and Boiler 3 is a Trane boiler with 57,680 lb/hr capacity at 230 psig. Boilers 1 and 2 were installed in 1976, and Boiler 3 was installed a few years later. Four cooling towers run all year round, including the summer months, and are cleaned in the spring and fall using an in-house work force. The cooling season should start the second week in April. Figure 25 shows chilled water piping and pumps inside the central plant.

The team also visited the wood burning plant (Figure 26). The plant has an E. Keeler water-tube boiler, installed in 1983, with 94,900 lb/hr capacity. The stack has no economizers. The plant is operated by a control system using Honeywell controls. Figures 27 through 32 show additional pictures from these areas taken during the site visit.

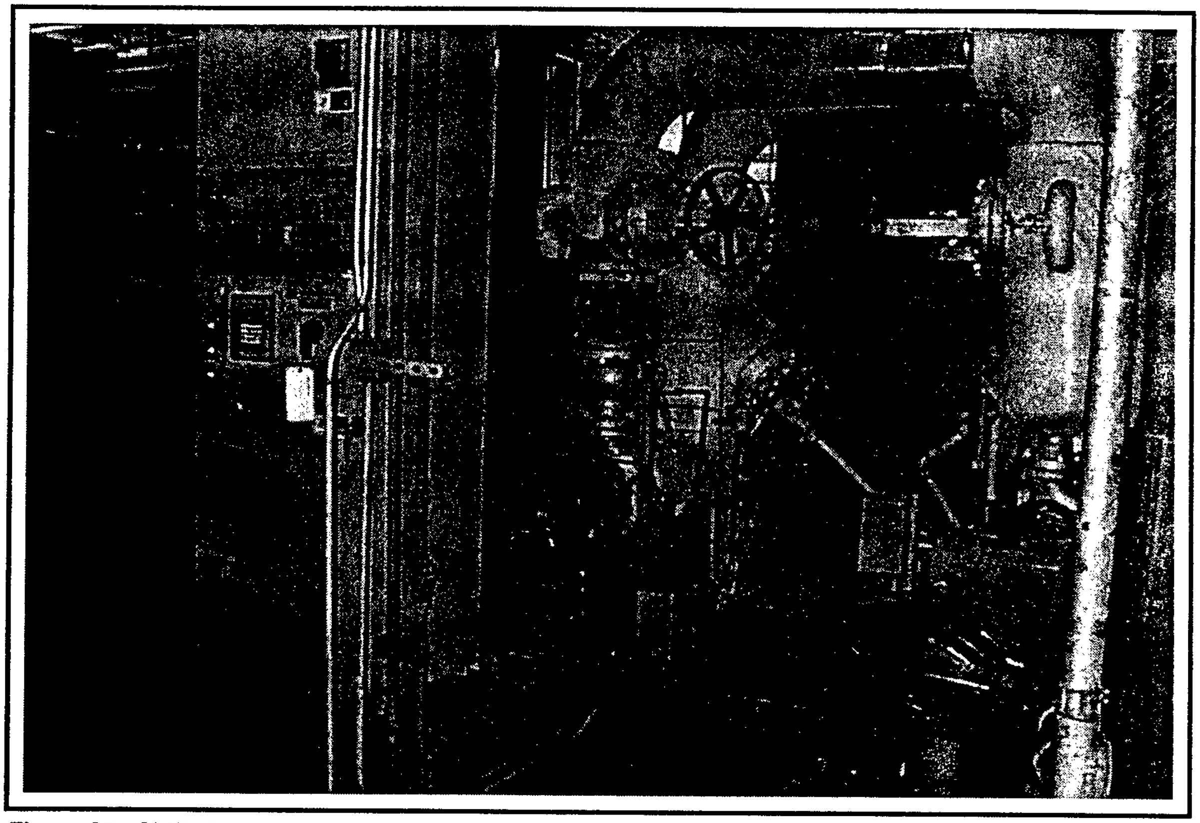

Figure 25. Chilled water piping and pumps in Building 1412.

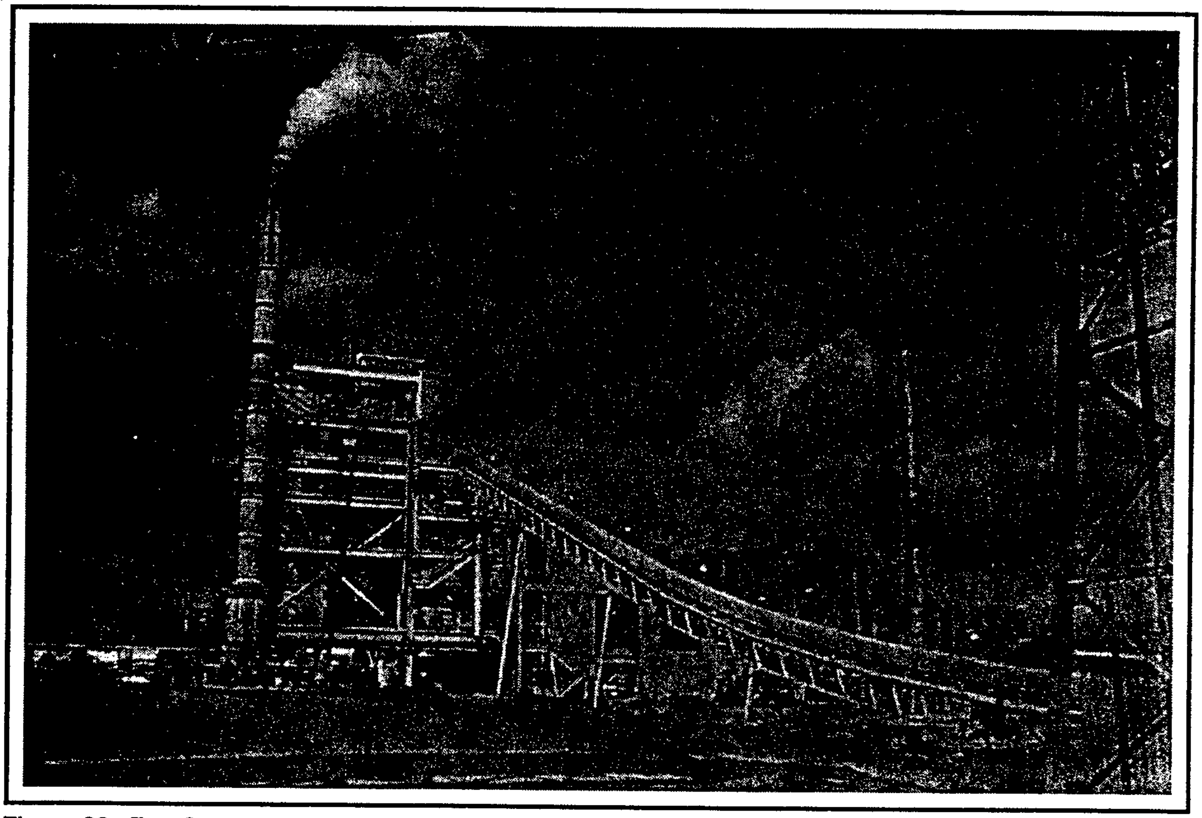

Figure 26. Fort Stewart wood burning plant.

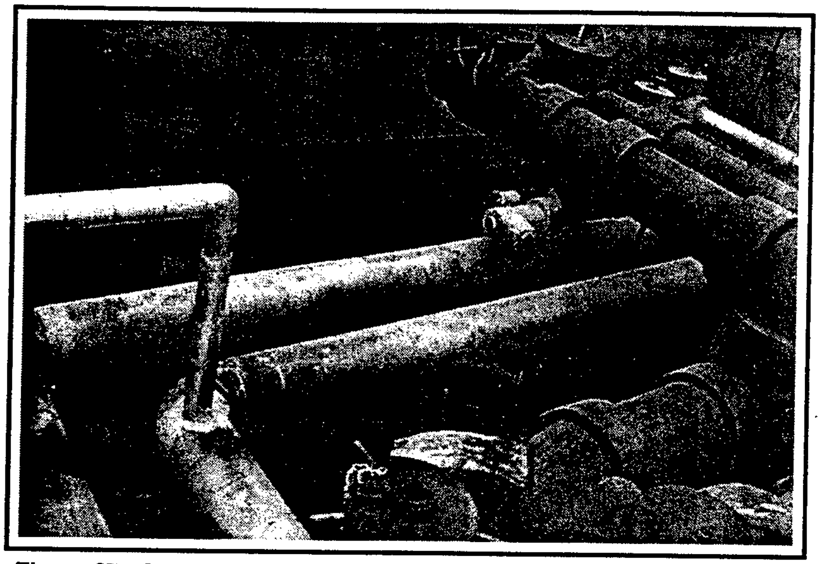

Figure 27. Condensate water leaks in valve pit.

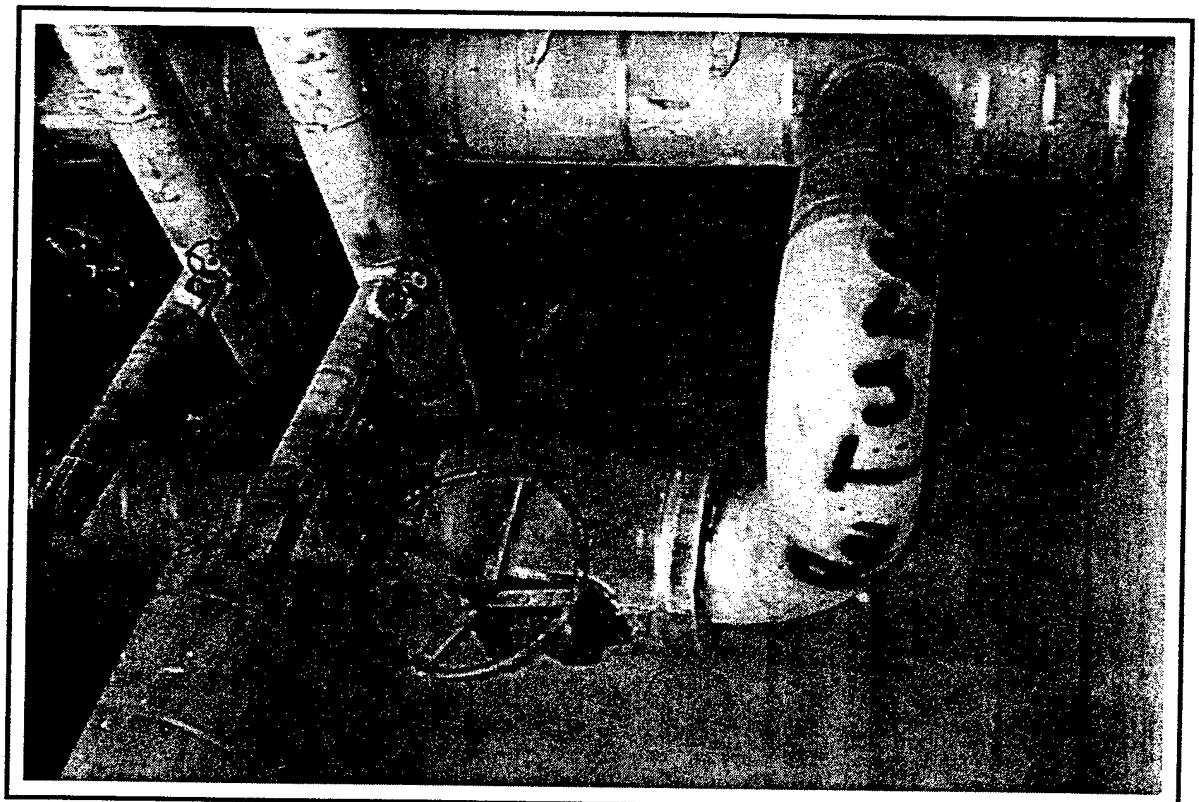

Figure 28. Fort Stewart steam distribution system return piping.

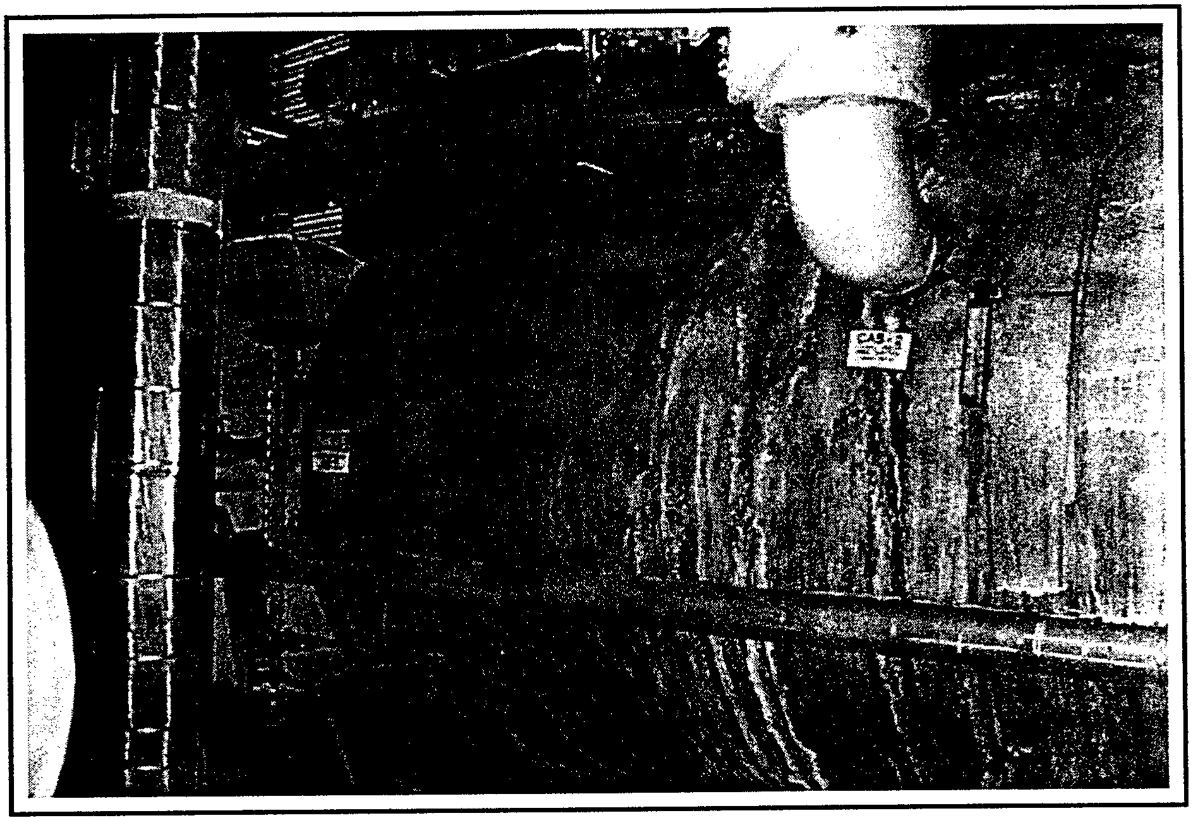

Figure 29. Makeup water tank at central plant.

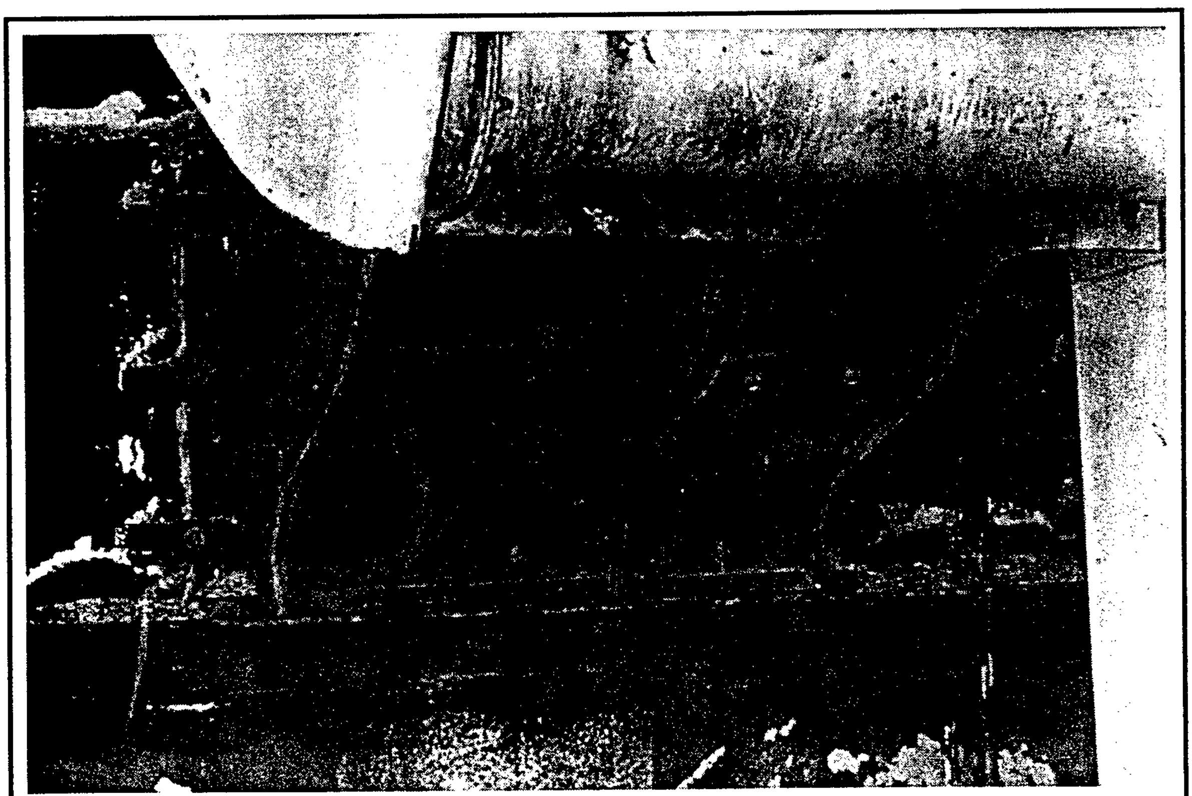

Figure 30. Corrosion in equipment.

Figure 31. Wood supply area.

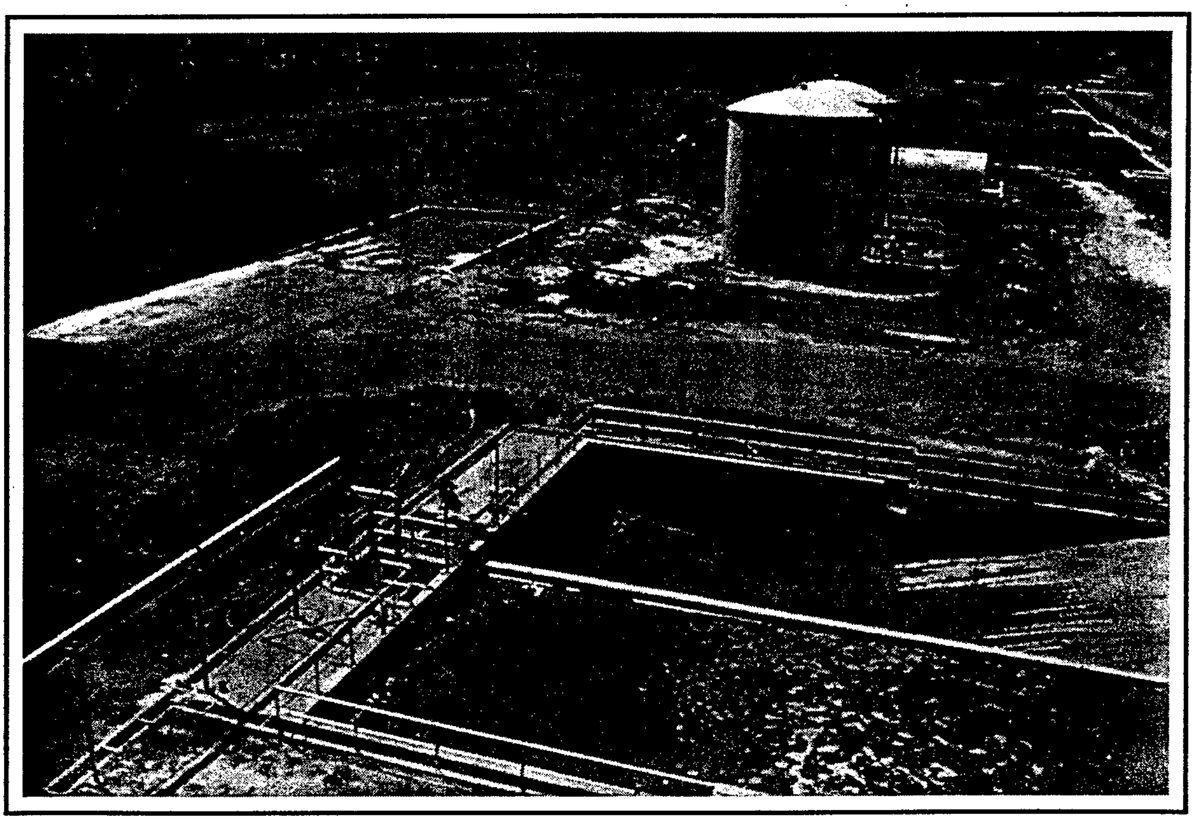

Figure 32. Scrubber waste storage.

Based on the Fort Stewart distribution map and CRREL's spreadsheet analysis from the IR study, CRREL designated Zone 3 as the distribution area requiring the most need for repair and replacement. The areas in Zone 3, including the central plant and the 200, 500, and 800 blocks, were determined to have 4 to 16 times the heat loss in the distribution system. CRREL is working on the final IR report. CRREL researchers commented that the valve pits were excessively deep, and that the groundwater table was quite high. CRREL also recommended replacement of direct-buried pipes with a shallow concrete trench. Researchers observed that Fort Stewart is an excellent candidate for shallow trench. The type of trench used will cost between \$10.5 M to \$15M. USACE Savannah District has expertise in shallow trench construction. CRREL also commented that the HTHW heat loss estimates are actually conservative because they do not include the losses to the adjacent chilled water piping.

CERL suggested that Fort Stewart should have HTHW generators. CERL also suggested that the steam turbine generator option should be reconsidered, with the alternative of adding more gas turbines or engines to trim the mechanical load. The service/capacity charge for the propane plant is based on the difference between fixed and interruptible rates. In comparing fuel cost estimates, oil was \$4.52/MBtu, wood \$2.00 to \$2.50/MMBtu (including labor for the wood yard), and natural gas \$3.00/MBtu. Fort Stewart stated that their DD1391 needed re-evaluation, with emphasis placed on distribution system losses. CERL also stated that Fort Stewart should retain the natural gas boilers, with the following enhancements: (1) separate induced-draft fans to establish better control, (2) temperature readouts, and (3) oxygen readouts to maximize combustion efficiency. A plan to coordinate cheap fuel with cheap heating/cooling needs to be established.

Observations from Fort Stewart Site Visit

The chilled water system at Fort Stewart is believed to be in fair condition. Makeup rates are low and known problems are few. Within the manholes observed by CRREL, the valves and piping for the chilled water were in fair to good condition.

The HTHW distribution at Fort Stewart is in overall poor condition. CRREL conducted an infrared survey of the system in July 1998. The survey showed that the heat losses of the sections CRREL surveyed are on average 4.5 times what they would be for a new system. The physical observations CRREL was able to make from the manholes would tend to support this result. A discussion of major deficiencies and problems that CRREL observed follows.

In all of the manholes CRREL investigated, the system burial depth was very deep (estimated at about 8 to 10 ft). The ground water table is reportedly high in this area and the soils are sandy. Thus there is essentially an unlimited supply of water available to penetrate the manhole walls or conduit casings. This puts even the best system at risk of failure, as any deficiency in the manhole envelope will allow it to flood if a sump pump fails. Similarly, any breach of the integrity of the heat distribution conduit such as a small defect in a field closure weld or corrosion penetration will result in conduit air space being flooded. Some portions of the system had cathodic protection, but the operation of the system was not verified. In some sections that Fort Stewart had excavated, the conduit was full of corrosion holes.

At each manhole CRREL visited, at least one vent pipe was steaming. All vents CRREL saw had been treated properly with standpipes coming up to near the surface level and "u" bends at top. CRREL saw a number of casings that were corroded through at the end plate juncture. A few of the manholes were suffering from the "perpetual pumping" scenario that results when the sump pump discharges to the surface at a manhole and it runs back in either over the sidewalls or through the soil. These could be remedied in most cases by extending the manhole side walls upward and locating the discharge downslope or just farther away.

CRREL researchers estimated that the HTHW system at Fort Stewart to last much longer than 5 years before major problems would begin to occur at high frequency. The newer sections of the system (approximately 15 years old) did not appear to be in any better condition than the older portions. By design, a drainable, dryable conduit system like the one used by Fort Stewart does not lend itself to repair once the system has been flooded multiple times, as would appear to be the case here. Even if the system could be repaired, dried out, and the insulation somehow restored, the depth of the system and the propensity of the manholes to flood would almost certainly result in rapid deterioration back to its present state. At this point, it would seem that replacement of the system is the only feasible alternative that will assure long-term reliable performance.

CRREL's recommendations for the HTHW replacement would be to use a shallow trench system. The manholes CRREL looked at were basically sound and adequately sized. These could probably be reused for the trench system. The current Army guidance to consider a shallow trench system as the first below grade alternative. This site is well suited to a shallow trench with its level terrain. Keeping things as shallow as possible will help prevent problems related to the high water table.

There should be efforts made to lower the supply temperature from the current 385 °F. It should be possible to get this down to 300 °F, possibility even lower. This will require some modifications at the central plant where the absence of feedwater pumps for the boiler places constraints on how the system is operated. Variable speed pumping that is already available at the plant (Figure 27) should also be used, but currently the absence of feedwater pumps precludes this possibility. Some areas in the 700 and 800 blocks have problems with inadequate circulation, apparently due to insufficient differential pressure between supply and return. This could be due to system design, or it could be a result of poor control at the buildings. This should be investigated by checking the control valve functioning and possibly by doing a HEATMAP analysis. The temperature differential between supply and return is currently very low at times. Proper control and pumping should make it possible to achieve a temperature differential of 100 °F under most circumstances. This will further reduce pumping energy and line heat losses.

6 Lessons Learned from Site Visits

Project Alternatives

In general, procedures for design/award projects are different for every installation. Each installation has different alternatives for central heating plant modernization. Table 3 summarizes the modernization projects.

Benefits of Shallow Trench versus Direct-Buried

The use of shallow trench systems results in better distribution system maintenance, compared to direct-buried piping. Table 4 lists the existing distribution systems by installation.

Table 3. Summary of CHP modernization projects.

Installation	Project Year	Project Type
Fort Riley, KS	FY99	Decentralization
Fort Eustis, VA	FY99	Decentralization
Redstone Arsenal, AL	FY00	Centralized steam system M&R
Fort Carson, CO	FY00	New direct-buried system
Fort Stewart, GA	FY01	HTHW distribution system repair and replacement
Fort Gordon, GA	FY02	Centralized heating/cooling distribution system M&R

Table 4. Summary of existing distribution systems.

Installation	Distribution Type	Existing System
Fort Riley, KS	Decentralized LTHW	Shallow trench/direct-buried
Fort Eustis, VA	Decentralized steam/LTHW	Aboveground
Redstone Arsenal, AL	Central steam	Direct-buried
Fort Carson, CO	Central HTHW	Direct-buried
Fort Gordon, GA	Central HTHW	Shallow trench
Fort Stewart, GA	Central HTHW	Direct-buried

Involvement of US Army Audit Agency with Projects

During FY99, the U.S. Army Audit Agency joined the utilities modernization support team to Redstone Arsenal, Fort Carson, Fort Gordon, and Fort Stewart. Successful completion of USAAA audits involves the installation providing the following critical information:

- Status quo economics
- Life cycle cost alternatives
- Economic analyses
- Validated savings.

A detailed heating study minimizes USAAA rework.

Issues Addressed by Installations

The primary issues addressed by each installation DPW visited during FY99 were:

1. Funding for design
2. DD1391 preparation, including the choice of documenting O&M savings and cost avoidance
3. Makeup water leakage (in gallons/day).

Buried District Heating Piping Assessment Tools

HEATMAP

An accurate HEATMAP model of the existing heat distribution system is an inexpensive, yet valuable tool for analyzing CHP modernization alternatives. DPW engineers can use the HEATMAP model to do the following for almost any proposed scenario:

- Optimize pipe sizes
- Calculate capital costs
- Estimate energy costs
- Estimate system heat losses
- Optimize system operation.

The results can then be sent automatically to the Life Cycle Cost in Design (LCCID) program (Lawrie 1988) for life cycle cost analysis.

The only information required for a HEATMAP analysis is a map of the distribution system (preferably in electronic format) and building area, and usage data. When available, metered data or other thermal loads analysis data should be used for consumer loads. If actual consumer load data is not available, HEATMAP will estimate the loads from the building area and usage information. Installations may obtain a copy of the HEATMAP program from CERL. CERL can provide assistance (on a reimbursable basis) with constructing and validating the HEATMAP model and analyzing modernization alternatives. CERL can also provide training for installations that wish to perform the HEATMAP analysis themselves.

The HEATMAP simulation relies on several estimates and assumptions to make calculations about the flow characteristics and thermal performance of the heat distribution system. It is therefore important to use actual steam flow and fuel consumption data from the installation to verify that simulation results are reasonable.

HEATER EMS

The HEATER Engineered Management System (EMS) (CERL 1999) is designed to help installations with inventory, condition assessment, condition prediction, and cost-effective maintenance and repair (M&R) planning for heat distribution systems (HDS). HEATER's inventory databases include information describing the components that comprise the HDS, such as pipes, manholes, and steam traps. HEATER also includes procedures for inspecting the HDS and calculating a quantitative condition index on a scale of 0 to 100 (worst to best). HEATER's condition prediction models forecast the system's deterioration over time and indicate when M&R is needed. Based on all of the this information, HEATER provides the user with multi-year M&R work plans that consider the life-cycle cost and functionality of the HDS.

To give the user a comprehensive analysis capability, HEATER is integrated with HEATMAP, which calculates flows, pressures, temperatures, and heat losses at various points throughout the HDS. HEATER can be used to calculate system operating cost for various scenarios. HEATMAP also provides an AutoCAD map of the HDS. It can be used to design a new system, evaluate the performance of an existing system, evaluate the feasibility of expanding a system to handle new construction, and determine the cost of system energy losses.

HEATER is a module of the Utilities EMS Suite, which is an integrated set of EMSs for heat, gas, water, and sewer systems, as well as a set of shared utility analysis tools.

Infrared Survey

Infrared thermography (Phetteplace 1999) provides a method for quantifying heat losses from the temperature profile of the ground's surface above the buried heat distribution pipeline. The first phase of the infrared thermography method is to acquire and review all available facility pipeline system plans and records. The types of data needed for the analysis include system routing, ground surface and pipeline elevations, manhole layouts, and heat distribution pipeline building entries. Additional data that would be collected include supply and return temperatures, weather data (including wind speed), prevalent soil types of the vicinity being surveyed, type of distribution system construction, and age. More detailed data would be collected once the survey team is familiarized with the site and the buried piping system being surveyed. System burial depth data would be obtained by conducting an elevation survey of the ground surface along the pipeline route combined with depth measurements obtained by entering each manhole.

The second phase of the infrared thermography method involves the infrared (IR) survey. An infrared scanner is mounted on a cart with a mast that places the camera about 3 m high, allowing a field of view of approximately 2 m high by 3 m wide for each image recorded. A two-person team typically conducts the IR survey when the site is in darkness. For the effects of daytime sunlight shadowing to disperse, the IR survey is normally conducted between the hours of 2200 and 0600. The infrared data collected consists of videotape recordings of the IR survey along with digital "snapshots." Each videotape enables the team to record 2 hours of surveying footage.

Wind speed data can be obtained via the National Oceanic and Atmospheric Administration (NOAA) web site. Soil classification and moisture content must be determined to estimate the thermal conductivity of the soil. Chapter 11 of the *1996 ASHRAE Systems and Equipment Handbook* provides a table of soil thermal conductivities based on soil moisture content (ASHRAE 1996).

The primary result from the infrared survey is the temperature profile of the ground surface above the buried heat distribution system. This temperature profile is deduced from the thermal image that the infrared scanner obtains. From this temperature profile, and the site and weather data collected, an estimate of the heat loss can be made using the so-called "TX method." Details on the TX method of analysis can be found in an ASHRAE symposium paper (Phetteplace 1999). The absolute heat loss from a buried district heating system pipe is dependent on the size of the pipe, the operating temperature, the burial depth, and several other factors. For this reason it is desirable to somehow put the

quantitative results of this infrared measurement method into perspective. For the studies CRREL has done to date using the TX method for each section of the heat distribution system, the heat loss has been calculated for a new pipe of the same size operating under the same conditions. For these calculations, the basic heat-loss calculation methods outlined in the ASHRAE Handbook (ASHRAE 1996) were followed, and the burial depth and soil properties specific to each system segment were used. Once the values for the heat loss of a new system were calculated, they were compared with the results obtained from the infrared measurements to obtain a ratio of measured existing heat loss to new system heat loss. This ratio is called the "replacement priority index" or "RPI." The RPI indicates which segments of the systems deviate the most from the expected heat loss for a new system. The sites where CRREL conducted infrared surveys were provided the RPI results from these surveys. These results can be used to directly determine which segments of the distribution system should be the highest in priority for replacement. The heat loss rates calculated may also be used by the sites to prepare LCC analyses that would determine payback periods for system replacements. While it is sometimes possible to estimate the condition of a buried heat distribution system from indirect and sometimes qualitative observations like system type and age, burnt grass, manhole conditions, and/or water samples, CRREL recommends the use of the TX method where infrared surveys are economically feasible. The TX method provides the only means currently available for non-destructive measurement of the true performance parameter of the heat distribution system, its efficiency in delivering heat to the buildings. CRREL is available on a reimbursable basis to conduct infrared surveys of heat distribution systems and perform TX analysis of the results.

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14. ABSTRACT

The purpose of the Central Heating Plant (CHP) Modernization Program is to modernize inefficient and failing heating plants and distribution systems so that they will provide the installations with safe, reliable, energy efficient and environmentally friendly service. This report documents site surveys and analyses that were conducted for the program during FY99. This report includes lessons learned from site visits and provides feedback to other installation DPWs that are considering modernization of their heating plants and distribution systems.

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